



# ASTRODATA

240 E. Palais Rd., Anaheim, California

DC AMPLIFIERS

no charge





# ASTRODATA

## ADVANCED SOLID STATE AMPLIFIERS FOR YOUR CONTROL AND INSTRUMENTATION APPLICATIONS

Astrodata advanced design instrumentation amplifiers raise state-of-the-art standards to higher levels for measurement... conditioning... monitoring... indicating... control.

Many standard options are available to adapt these amplifiers to your individual requirements.

For custom designs, Astrodata's extensive experience provides a well-qualified capability for satisfying your specific performance needs.

**Model 884 Wideband (dc-150kc) Floating, Guarded Amplifier...**

**Model 885 Wideband (dc-10kc) Differential Amplifier...**

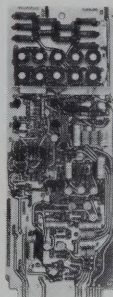


high-gain/high-performance amplifiers for low-level wideband systems. Completely transistorized, these state-of-the-art amplifiers use field-effect transistors in place of the mechanical choppers to achieve lowest drift rate, low power consumption and maximum reliability. Standard gain steps include "OFF," 3, 10, 30, 100, 300 and 1,000. Continuously adjustable 10-turn vernier control is available as a standard option. An optional  $\pm 10$  ma or  $\pm 100$  ma output current (at  $\pm 10$  volts), supplied from low output impedance, can be supplied to drive A to D converters, multiplexers, galvanometers or tape recorders. The Model 885 provides a choice of transfer characteristics, including (A) Maximally Flat Amplitude (Butterworth) for widest frequency response in high-level multiplexed, galvanometer or tape recorder systems, or (B) Linear Phase (Bessel) for fastest settling time and overload recovery time in low-level multiplexed systems.

Both models have built-in power supplies, feature drift less than  $2\mu\text{V}$  per week, noise less than  $4\mu\text{V}$  rms, linearity better than 0.02%.

**Model 117 100-volt Operational Amplifier** for analog control or computer systems.

OUTPUT:  $\pm 100$  volts  
at  $\pm 50$  ma  
BAND WIDTH: dc to 200kc  
GAIN: Greater than  $10^8$   
NOISE REFERRED TO INPUT: 2 mv rms  
INPUT RESISTANCE: 3 megohms at dc, 1 megohm above 5 cps



**Model 133B Dual-Channel Galvanometer-Driven Amplifier** provides 18 independent amplifier channels in 7 inches of panel space.

GAIN RANGE: Zero to 4, with ten-turn, continuously variable, locking control  
INPUT IMPEDANCE: 10,000 ohms  
FREQUENCY RESPONSE:  $\pm 0.5$  db from dc to 20 kc  
OUTPUT LIMITING:  $\pm 100$  ma maximum output current prevents galvanometer overload or burnout.



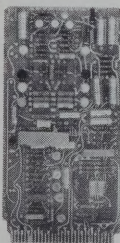
**Model 880 Differential Amplifier** for low-level, low-frequency systems.

BANDWIDTH: dc to 100 cps; also available with switch-selected active filters.  
LOW NOISE: less than  $1\mu\text{V}$  rms  
GAIN RANGE: 50-1000  
MOUNTING: Portable case or 8-in standard rack mounting frame



**Model 112 Chopper-Stabilized Operational Amplifier.** Versatile, modular for analog control systems.

BANDWIDTH: dc — 250 kc  
Long-term stability, constant gain-bandwidth  
OPEN LOOP GAIN: Adjustable from  $10^7$  to  $2 \times 10^8$  for constant gain-bandwidth.  
Offset adjustable to zero ( $\pm 1$  mv. nom. range)  
VOLTAGE OFFSET DRIFT: Less than  $6\mu\text{V}$  per hour  
INPUT CURRENT: Less than 1 na



**Model 120 Nanovolt Amplifier** gives you high-gain/low-noise amplification for seismic transducer signals, cryogenic studies, thermocouple or strain gage signals.

GAIN RANGE: 200 to 1,000,000  
BANDWIDTH: dc — 100 cps  
NOISE:  $0.05\mu\text{V}$  rms referred to input  
INPUT RESISTANCE: 1 megohm  
OUTPUT LEVEL: 0 to  $\pm 5$  volts at  $\pm 5$  ma



**Model 121 Nanovoltmeter** provides  $0.1\mu\text{V}$  full scale bridge balance detector or thermocouple indicator for standards and calibration work, in the field as well as in laboratories.

FULL SCALE RANGES:  $\pm 0.1\mu\text{V}$  to  $\pm 100$  mv  
INPUT RESISTANCE ALL RANGES: 1 megohm  
Built-in Overload Indicator  
Self-Contained Batteries and AC Power Pack



Contact your Astrodata engineering representative for a demonstration... or write today for technical literature giving complete specifications.



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P.O. Box 3003 • 240 East Palais Road • Anaheim, California 92803

Phone (714) 772-1000

TWX 714-776-3760





CATALOGUE  
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Some examples of **ASTRODATA's** data acquisition and processing systems capabilities, calibration and conditioning systems, solid-state instrumentation amplifiers, time code generators, translators and tape search systems.

## SHORT FORM CATALOGUE



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CATALOGUE



# ASTRODATA

## STANDARD SOLID STATE AMPLIFIERS FOR YOUR INSTRUMENT AND CONTROL SYSTEMS



Astrodata **standard** instrumentation amplifiers are designed for use with data acquisition systems to raise low level signals to useful levels for measurement, conditioning, monitoring, feedback loop control and indication. Many performance options are available to adapt these standard amplifiers to a wide range of applications.

Where custom designs are necessary, Astrodata's experience provides an exceptionally well qualified basis for meeting your individual requirements.

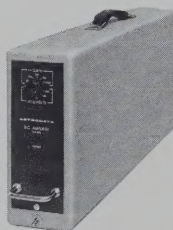
**TDA-875 Dual-Mode Amplifier** for both portable cabinet and rack mounting installations.

**TDA-875 Dual-Mode Amplifiers** for both differential and single-ended, floating amplification after low-level commutation.

DIFFERENTIAL BANDWIDTH dc — 5 kc  
SINGLE ENDED BANDWIDTH dc — 150 kc  
COMMON MODE REJECTION Greater than 120 db dc to 60 cps  
RECOVERY TIME FROM 20 VOLT OVERLOAD 1 millisecond

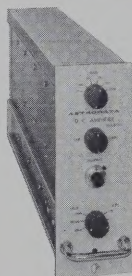
**TDA-874 Wide-Band Single Ended Amplifier** for amplification after low level commutation.

BANDWIDTH  
dc — 150 kc  
GAINS AVAILABLE FROM  
1 — 5000  
NOISE REFERRED  
TO INPUT  
5 mv rms  
INPUT RESISTANCE  
Greater than  
100 megohms



**TDA-874G Galvanometer Driver Amplifier** for raising low level sources to galvanometer levels.

Built-in Galvanometer  
Overload Protection  
ADJUSTABLE DAMPING  
RESISTOR  
0 — 1000 ohms  
GAIN RANGE  
0.5 — 5000  
INPUT RESISTANCE  
Greater than  
100 megohms

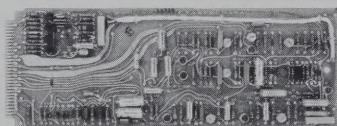


**TDA-880 Differential Amplifier** for single channel or high-level multiplexing systems.

BANDWIDTH  
dc to 200 cps  
LOW NOISE  
1  $\mu$ v rms  
Built-in Filtering  
Available to Restrict  
Bandwidth for  
Commuted Data  
Systems.



**TDA-110 Chopper Stabilized Operational Amplifier.** Versatile modular amplifier for analog control systems.



BANDWIDTH dc — 250 kc  
Long Term Stability, Constant  
Gain-Bandwidth  
VOLTAGE OFFSET ADJUSTABLE TO ZERO  
 $\pm 1$  mv nom. range  
CURRENT OFFSET ADJUSTABLE TO ZERO  
 $\pm 0.001$   $\mu$ a nom. range

**TDA-121 Nanovoltmeter** provides 0.1  $\mu$ v full scale bridge balance detector for standards and calibration work in the field as well as laboratories.

FULL SCALE RANGES  
 $\pm 0.1$   $\mu$ v to  $\pm 100$  mv  
INPUT RESISTANCE  
ALL RANGES  
1 megohm  
Built-in Overload  
Indicator.



**TDA-120 Ultrasensitive Amplifier** gives you high gain/low-noise amplification for seismic transducer signals, cryogenic studies, strain gage signals.

Gains From 1000 to  
100,000 (optional to  
3,000,000).  
BANDWIDTH  
dc — 100 cps  
NOISE  
0.05  $\mu$ v rms  
referred to input  
INPUT RESISTANCE  
1 megohm



Contact your Astrodata Engineering representative for a demonstration... or write today for technical literature giving complete specifications.



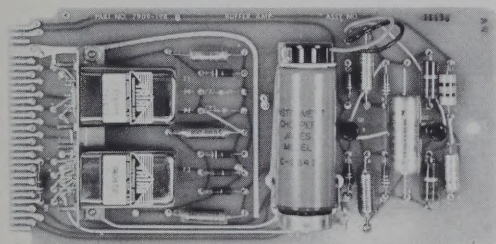
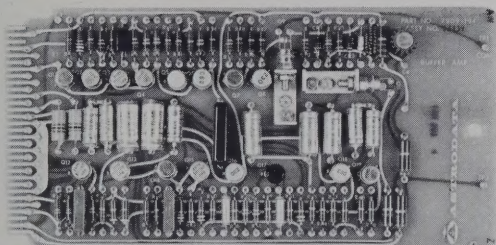
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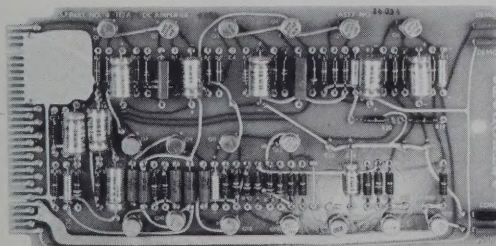
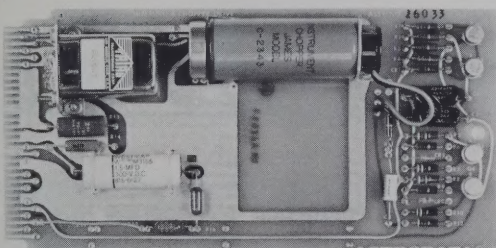
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## STANDARD SOLID STATE AMPLIFIERS FOR YOUR INSTRUMENT AND CONTROL SYSTEMS



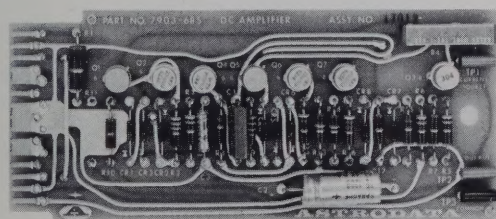
### MODEL 115 ADJUSTABLE GAIN POTENTIOMETRIC AMPLIFIER — CHOPPER STABILIZED

|                   |                               |
|-------------------|-------------------------------|
| Bandwidth         | dc to 150 kilocycles          |
| Gain              | Adjustable 1 to 200           |
| Input Resistance  | 100 megohms                   |
| Output Resistance | Less than 1 ohm               |
| Output            | $\pm 10$ volts at $\pm 20$ ma |
| Settling Time     | 25 $\mu$ sec to 1%            |
| Noise             | Less than 5 $\mu$ v rms RTI   |
| Drift             | 2 $\mu$ v/week RTI            |
| Power Req.        | $\pm 18$ v dc at 100 ma       |



### MODEL 116 HIGH-GAIN POTENTIOMETRIC AMPLIFIER — CHOPPER STABILIZED

|                   |                                |
|-------------------|--------------------------------|
| Bandwidth         | dc to 5.33 cps                 |
| Gain              | $555.5 \pm 0.06\%$             |
| Input Resistance  | 20 megohms                     |
| Output Resistance | Less than 1 ohm                |
| Output            | $\pm 10$ volts at $\pm 10$ ma  |
| Noise             | Less than 0.4 $\mu$ v rms RTI  |
| Drift             | Less than 2 $\mu$ v RTI/6 mos. |
| Power Req.        | $\pm 18$ v dc at 50 ma         |



### MODEL 140 WIDEBAND POTENTIOMETRIC AMPLIFIER

|                   |                        |
|-------------------|------------------------|
| Bandwidth         | dc to 100 kilocycles   |
| Gain              | Unity $\pm 0.01\%$     |
| Input Resistance  | 1 megohm               |
| Output Resistance | 15 ohms                |
| Output            | $\pm 5$ volts at 1 ma  |
| Noise             | 0.5 millivolts rms     |
| Drift             | 10 mv/d days           |
| Power Req.        | $\pm 12$ v dc at 10 ma |

Bulletin Number 620711

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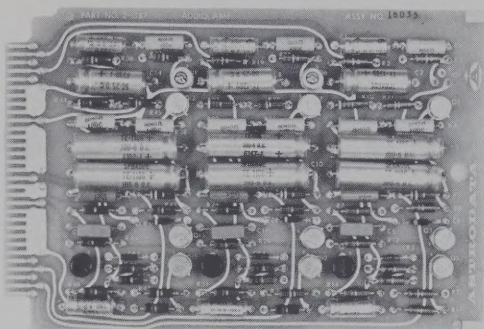
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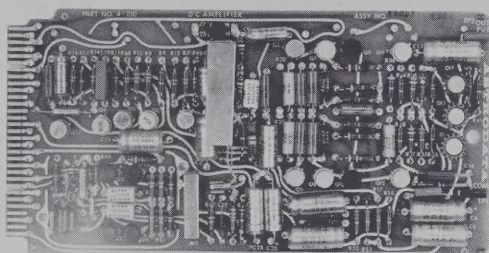
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## STANDARD SOLID STATE AMPLIFIERS FOR YOUR INSTRUMENT AND CONTROL SYSTEMS



### MODEL 108 AUDIO AMPLIFIER

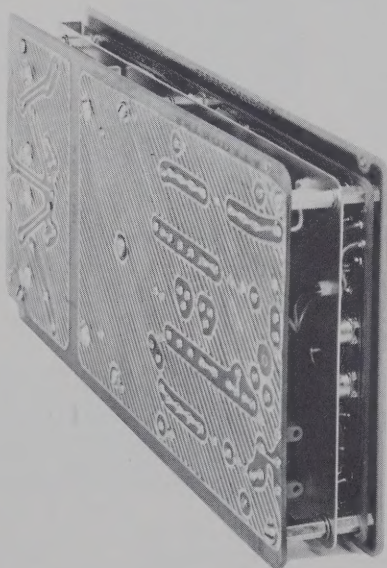
|                     |                                                    |
|---------------------|----------------------------------------------------|
| Gain (each channel) | 46 db                                              |
| Frequency Response  | $\pm 1/2$ db 20 to 20 Kc<br>$\pm 3$ db 5 to 100 Kc |
| Input Z             | 604 ohms                                           |
| Output Z            | Less than 1 ohm                                    |
| Power Output        | 100 milliwatts                                     |
| Noise               | Less than 1 $\mu$ V RTI ( $-118$ db)               |
| Harmonic Distortion | Less than 0.1%                                     |
| Power Requirements  | $\pm 18$ volts dc at 75 ma                         |



### MODEL 112 HIGH-SPEED OPERATIONAL AMPLIFIER — CHOPPER STABILIZED

|                   |                                      |
|-------------------|--------------------------------------|
| Bandwidth         | dc to 1 megacycle                    |
| Gain (open loop)  | Adjustable $10^3$ to $2 \times 10^5$ |
| Input Resistance  | 100,000 ohms dc<br>20,000 ohms ac    |
| Output Resistance | Less than 1 ohm                      |
| Output            | $\pm 10$ volts at $\pm 10$ ma        |
| Settling Time     | 10 $\mu$ sec to 0.01%                |
| Noise             | Less than 100 $\mu$ V                |
| Drift             | 6 $\mu$ V/hour                       |
| Power Req.        | $\pm 18$ v dc at 40 ma               |

Bulletin Number 620801



### MODEL 113 WIDEBAND POTENTIOMETRIC AMPLIFIER — CHOPPER STABILIZED AMPLIFIER FLOATING FROM POWER SUPPLY

|                  |                               |
|------------------|-------------------------------|
| Bandwidth        | dc to 1 megacycle             |
| Gain             | unity $\pm 0.01\%$            |
| Input Impedance  | 100 megs. dc + 10 $\mu$ f     |
| Output Impedance | Less than 1 ohm               |
| Output           | $\pm 10$ volts at $\pm 10$ ma |
| Settling Time    | 10 $\mu$ sec to 0.01%         |
| Noise            | Less than 250 $\mu$ V rms     |
| Drift            | 15 $\mu$ V/day                |
| Power Req.       | + 18 v dc at 150 ma           |

### MODEL 114 WIDEBAND POTENTIOMETRIC AMPLIFIER

|                  |                               |
|------------------|-------------------------------|
| Bandwidth        | dc to 1 megacycle             |
| Gain             | unity $\pm 0.01\%$            |
| Input Impedance  | 100 megs. dc + 10 $\mu$ f     |
| Output Impedance | Less than 1 ohm               |
| Output           | $\pm 15$ volts at $\pm 10$ ma |
| Settling Time    | 10 $\mu$ sec to 0.01%         |
| Noise            | Less than 250 $\mu$ V rms     |
| Drift            | 15 $\mu$ V/day                |
| Power Req.       | + 18 v dc at 200 ma           |

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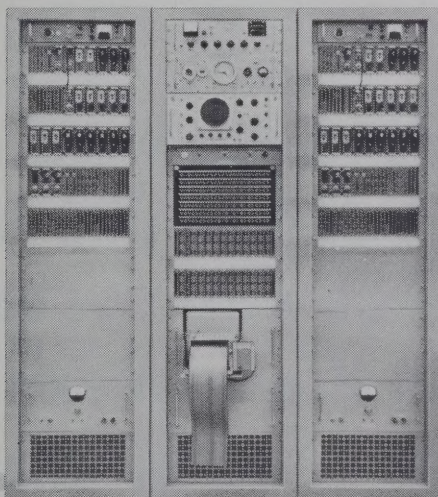
# ASTRODATA

## CUSTOM TIMING SYSTEMS FROM STANDARD ASSEMBLIES

You get solid state timing systems tailored to your specific requirements—from sophisticated range timing systems to portable instrumentation—with Astrodata's unique, building-block production technique.

For example, you can select fundamental

units from the table below, then designate standard options to obtain exactly the timing functions most suited to your particular requirements. Numerous standard options have been designed and built to provide you with the most versatile—and highly reliable—timing equipment available today.



### TIME CODE GENERATING SYSTEMS

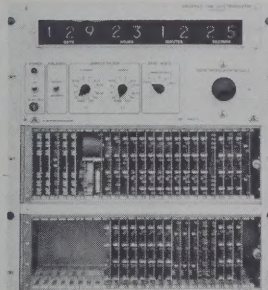
IRIG, NASA, AMR, PMR, White Sands, Eglin and special codes available

**Model 6190** Up to 8 serial time codes simultaneously... standard pulse rates... decimal display... stability to 1 part in  $10^8$ .

**Model 6140** Up to 4 serial time-of-day codes simultaneously... standard pulse rates... decimal display... stability to 1 part in  $10^8$ .

**Model 6100** Up to 4 serial time-of-day codes... standard pulse rates... binary display... stability to 1 part in  $10^8$ .

### TIME CODE TRANSLATOR SYSTEMS



**Model 6220 UNIVERSAL**... translates all serial time codes to decimal display... parallel BCD output. Tape Search and Control Units (Models 6224, 6225, 6226) available for universal automatic tape search.

**Model 6204** translates serial time code... provides parallel

output and display consistent with input code format.

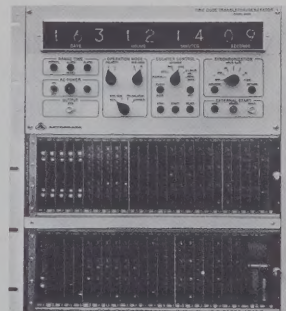
**Model 6201** translates time-of-day serial code to parallel output and binary display.

**Model 6200** converts input serial time codes to time-of-day display.

### TERMINATING SYSTEMS

**Model 6420 TIME CODE TRANSLATOR/GENERATOR**... operates as Translator and/or generator... synchronizes time code generator to input serial time code... no interruption of output on loss of input signal.

**Model 6620** Timing terminal unit... provides basic module for standard terminal function assemblies... can be assembled to provide any necessary terminal, signal conditioning or conversion functions... assemblies available: AGC amplifiers, demodulators, neon drivers, high level amplifiers, balanced line drivers, galvo amplifiers, relay drivers.



A new 48-page handbook of the most commonly used time code formats has been compiled as a handy reference for instrumentation engineers. For your free copy write to

For applications assistance when considering your timing system, contact your nearest Astrodata representative or the Timing Instrumentation Group direct.

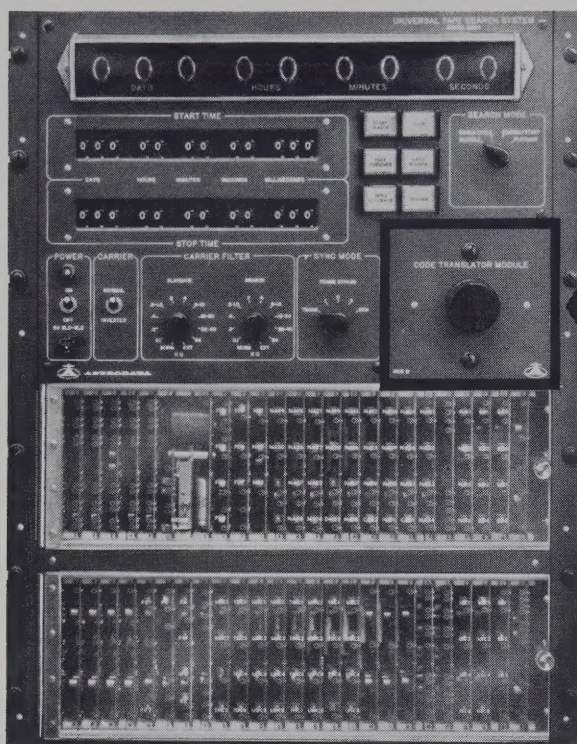


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# When a new time code is introduced...

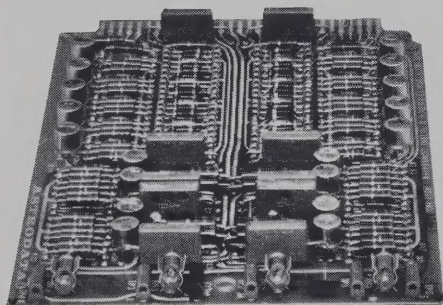


this plug-in module  
is all you need

to bring your  
Astrodata universal  
tape search system  
up to the minute

Astrodata Model 6222 Universal Automatic Tape Search System accepts virtually any time code format, and provides completely automatic high-speed search, playback, re-record and stop operations. Extremely high input sensitivity (10 mv) assures highly reliable tape search.

## ...to forestall system obsolescence



Indicative of the MIL-type quality built into Astrodata timing equipment are the many extras carefully designed and incorporated into each system. The circuit cards, for example, are glass epoxy boards for maximum resistance to moisture and temperature; test points and indicator lights on the cards facilitate easy system checkout from the front without removing the cards. Included also are such construction refinements as strain-relief mounted components, tin immersion plated mounting eyelets, rhodium-plated connector contacts, taper pin connector contacts, "worst-case" operating tolerances for all components.

Astrodata Model 6222 Universal Automatic Tape Search System has been designed to prevent system obsolescence each time a new time code format is introduced. Circuitry common to all time code translating is built into the system—circuitry peculiar to each time code is built into individual plug-in modules.

When working with IRIG, NASA, AMR and other formats already in existence, you merely insert the appropriate plug-in module to change from one code format to another. When a new time code format is introduced, it is necessary only to add a corresponding plug-in module.

All solid-state construction, using exceptionally conservative design criteria, gives you maximum protection against downtime. More than 40 systems have been installed to date. All customers report excellent operation...names on request.

Considerable savings accrue to users because of Astrodata's years of experience in the design and manufacture of time code generation, translation, telemetry and tape search systems combined with a modular approach that permits many engineering and production economies.

Astrodata produces a complete line of timing instrumentation. Write today for your copy of the new tape search brochure, or contact your nearest Astrodata representative.

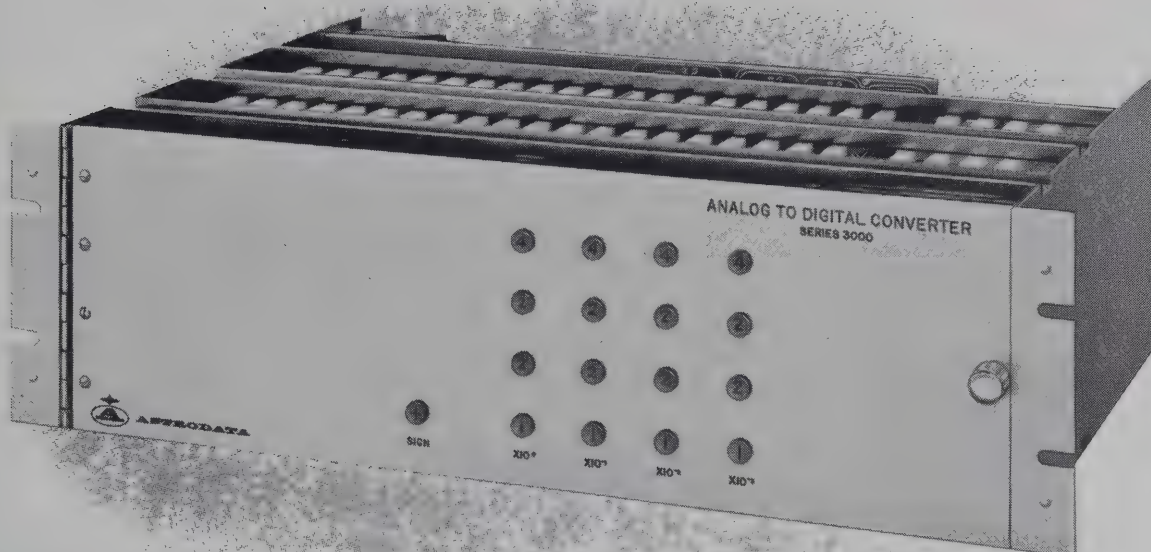


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# LOW COST ADC's

with accuracies to 0.01%  
and conversion speeds to 20,000 per second



Here is a whole family of new  
high performance/high speed Analog-to-Digital Converters  
designed to fit the requirements of virtually all data acquisition systems.

ASTRODATA Series 3000 line of Analog-to-Digital Converters offers you 1088 standard production models produced from a library of 13 basic circuit cards. From these, you can select full scale range... speed... accuracy... sample-and-hold... resolution... output format to meet your specific requirements.

Where highest speed is desired, decisions are made at the rate of 2.5 microseconds per bit, yielding 20,000 or more conversions per second for 10-binary bit converter. Where max-

imum accuracy is required, a basic accuracy of 0.01% is provided with decisions made at the rate of 4 microseconds per bit, yielding approximately 13,500 conversions per second for 14-binary bit converters.

Especially suited for use with time-multiplexed input data, Series 3000 ADC's provide high speed, ultimate accuracy, reliability and modular plug-in construction in one compact package... maximum value for your instrumentation dollars.

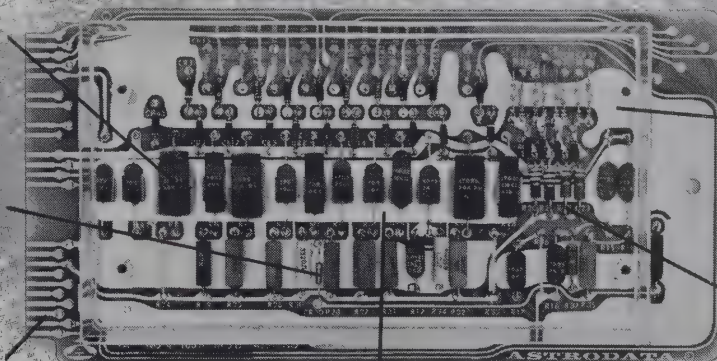
HIGH RELIABILITY ASSURED BY EXCELLENCE OF CONSTRUCTION AND CONSERVATIVE COMPONENT DE-RATING

Resistor networks are matched to  $\pm 0.002\%$ ; all accuracy-determining resistors have temperature coefficient ratio of less than 2 ppm/ $^{\circ}\text{C}$  for 0.01% accuracy converters.

Zener diodes pre-aged and temperature-cycled for 1000 hours and certified to exhibit less than 20 ppm (0.002%) drift per 1000 hours for 0.01% accuracy converters; less than 100 ppm (0.01%) drift per 1000 hours for 0.05% accuracy converters.

Integral circuit card connector reduces number of interconnections, enhances reliability.

## MOST SIGNIFICANT DIGITS CONVERTER NETWORK



Thermal gradients minimized by potting in GE LTV-602 silicone potting compound that assures isothermal operation of all components. Slitting compound with knife permits easy removal of components. Metal cover (not shown) helps equalize temperatures, provides mechanical protection.

Strain-relief loops assure high component reliability.

All accuracy-determining components mounted on common heat sink.

Contact your Astrodata engineering representative for a demonstration or write today for technical literature giving complete specifications.



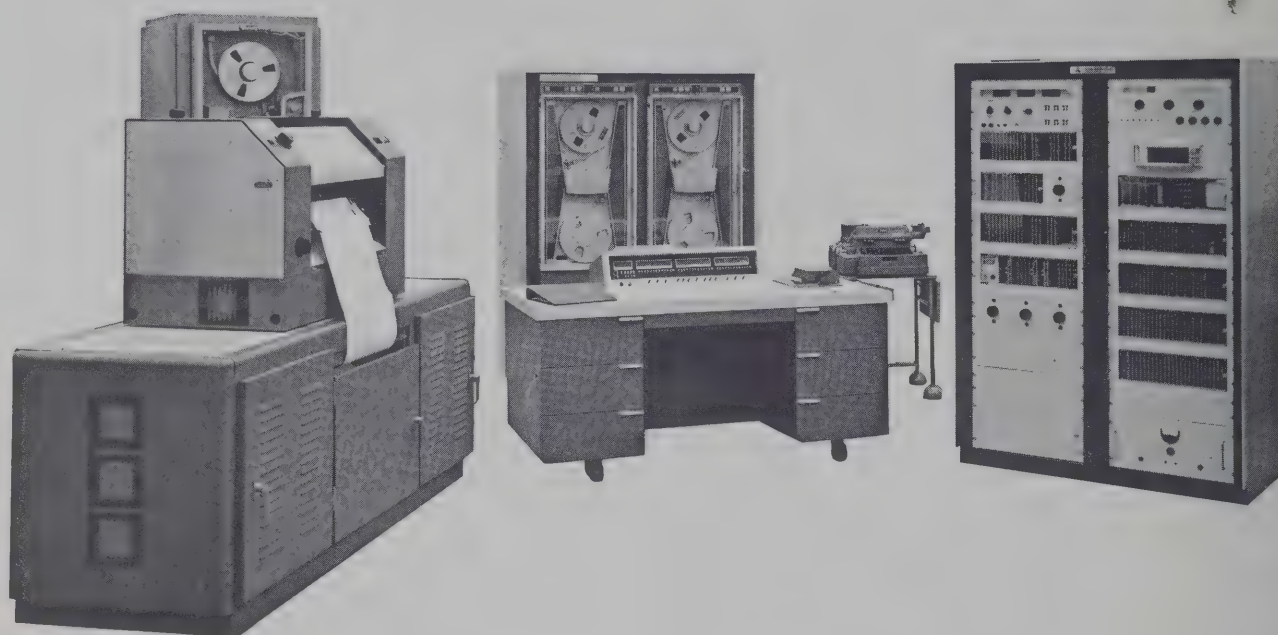
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## DATA CONTROL SYSTEMS



### ON-LINE COMPUTER REDUCTION OF TELEMETRY DATA

This telemetry system was developed by ASTRODATA, Incorporated for the U. S. Air Force. It utilizes an on-line, general-purpose, digital computer to decommutate and record telemetry data.

The system recognizes the various telemetry signal formats and processes these signals into conventional computer-compatible magnetic tape format. This tape may then be processed by normal digital computer routines to present the information in engineering units.

All rule-obeying functions are relegated to an on-line digital computer. Only such minimum peripheral equipment as will allow the computer to reduce and process data properly is included. Logic to determine format, synchronization, valid data, etc. is redundant in the presence of an on-line computer, therefore such equipment is not included in the system.

The system will process FM/FM, PAM and PDM data.

PAM pulse rates from 50 pps to 5000 pps and PDM pulse rates from 50 pps to 1000 pps can be handled.

Reduction of the above types of telemetry data requires only that the time

of occurrence and magnitude of the signal segments be noted. From these two facts the digital computer automatically determines format, synchronization, pulse rate, data value, and validity of signals.

The following table relates the type of time of occurrence and magnitude data sent to the computer for the various telemetry signals.

| Telemetry Signal | Time of Occurrence | Magnitude      |
|------------------|--------------------|----------------|
| FM (analog)      | digitizing rate    | amplitude      |
| PAM              | start of pulse     | amplitude      |
| PDM              | start of pulse     | pulse duration |

The time of occurrence and magnitude signals are written on a gapped-format intermediate magnetic tape through the digital computer's core storage and tape write circuits. This intermediate tape is then processed by the computer during a second pass. The data output presentation can be in some conventional form such as listings or plots of the reduced data. Digital-to-analog converters are provided for plotting analyzed data. Computer-compatible tape suitable for further computer analysis and processing is also prepared.

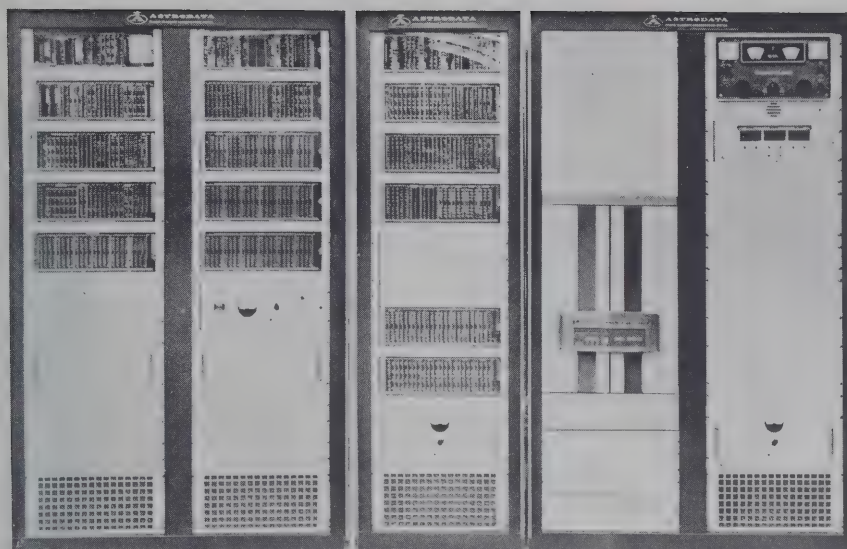
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or write today for technical literature  
giving complete specifications.



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#### REMOTE TELESCOPE COMMUNICATION AND CONTROL SYSTEM

The Remote Telescope Communication and Control System communicates with and controls a remotely-located telescope. An on-line, general purpose, digital computer is an integral part of the system. The system equipment at the Telescope Site automatically accepts analog and digital data from the telescope, digitizes the analog inputs, transmits a Barker Word for synchronization purposes, performs a longitudinal parity check on the resulting data, and delivers it to the system equipment at the Control Center in a bi-phase modulated, 1024-cps carrier form. Thirty channels of telescope-response information are multiplexed into an 11-bit straight binary analog-to-digital converter and the digitized data is transmitted, one bit at a time, to the Control Center. Data is recovered at the Control Center with a high degree of accuracy even under severe noise-to-signal ratios. The recovered data, the time-of-day from a sidereal clock, and any manual commands entered at the Control Console by the operator are delivered automatically to the computer.

The computer (a Packard Bell PB250) communicates with the Control Center, asynchronously, through a 22-bit high-speed buffer register. Information is sent out through this register for transmission to the Telescope Site and for display on the Control Console. Upon command from the computer, the high-speed buffer register accepts parallel, binary, information from the Control Center equipment. The computer then decodes this information and makes a continuous visual display at the console of the Right Ascension, Declination, Zenith Distance and Azimuth of the telescope.

The status of the Shutter, Dome, Registers and Encoders is displayed at the Control Console as well as digital or "go/no-go" information that the operator has programmed and patched to the unassigned displays on the con-

sole. Provisions are also made on the console for 100 pre-programmed sub-routines to be carried out by the computer upon manual command.

The aforementioned displays on the console are all driven from decoders that operate, through a patchboard, from seven of the output registers. The computer loads these registers from decoded data that was generated at a patchboard.

Manual remote control also originates at the Control Console. Changes in telescope position can be entered via a telephone dial. The operator selects the type of change desired (plus or minus, declination or right ascension) and dials four digits. These are entered into a register and simultaneously displayed.

A longitudinal parity check is made upon the incoming data for indication of validity. The Control Center then transmits a 512-cps, bi-phase-modulated signal back to the Telescope Site. This signal contains a longitudinal parity bit, a Barker Word configuration (for synchronizing purposes) and computer-generated data words to be used for control of the telescope.

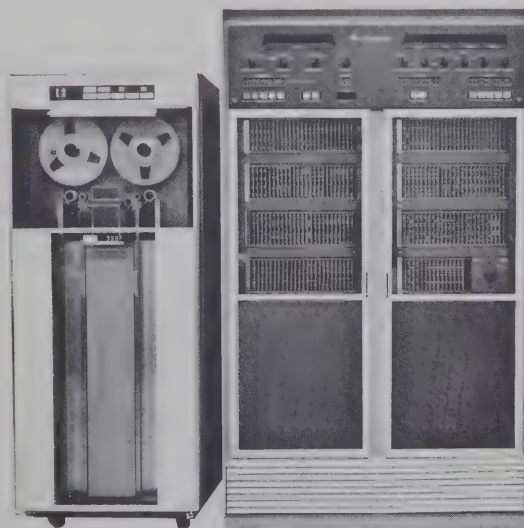
The same data transmission and data recovery methods are used in going from the Control Center to the Telescope Site as are used when the flow of data is in the opposite direction. The synchronization and data recovery logic at the Telescope Site recover the data, shift it in serial fashion through a 32-bit data shift register and store it in sixteen 32-bit output storage registers, under control of a patchboard. The outputs of the sixteen storage registers are available at the rear of the cabinets for driving digital positional motors. These motors are automatically put in "stand-by" when the computer is operated off-line, so as to discontinue movement of the telescope.

#### HIGH-SPEED TELEMETRY DATA REDUCTION SYSTEM

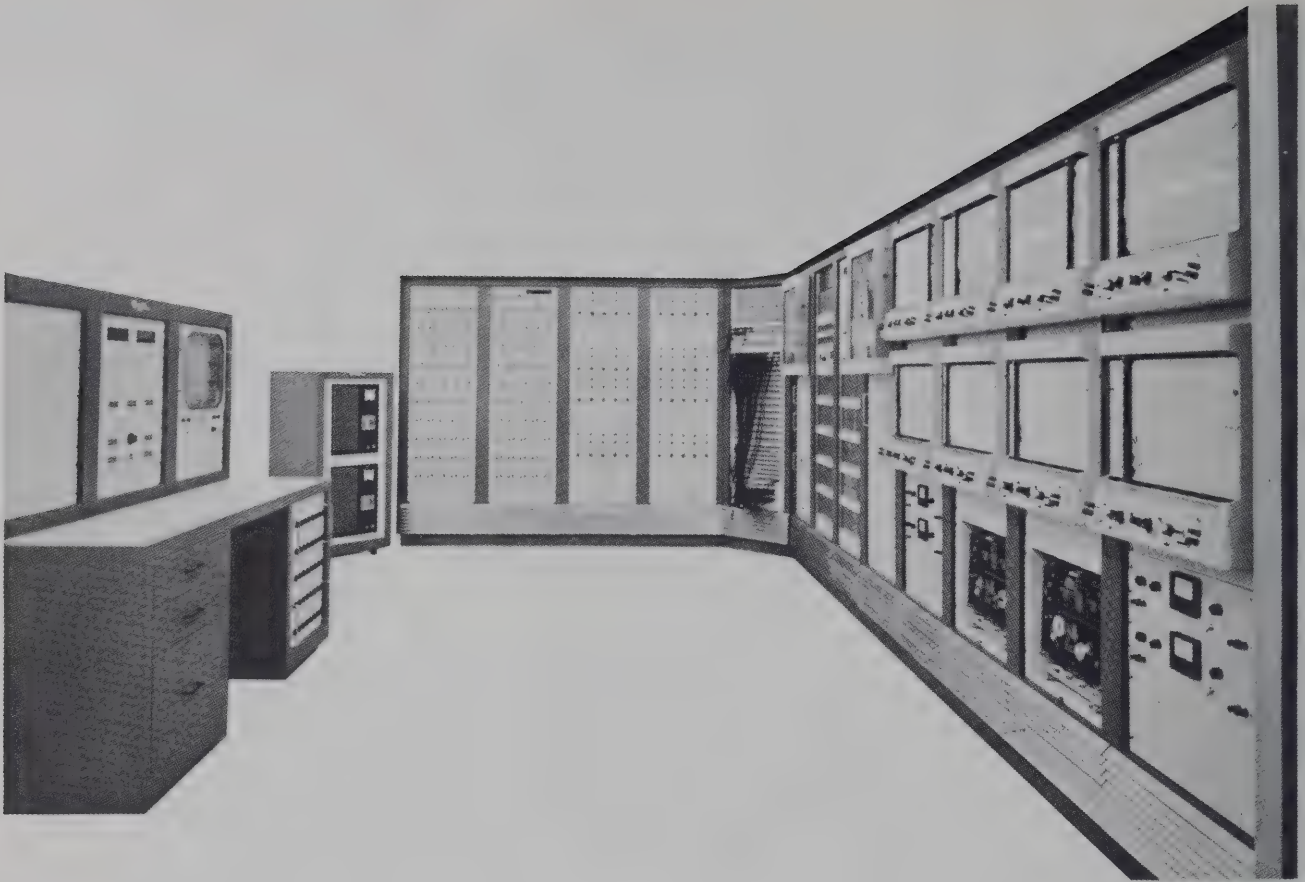
This system accurately prepares computer-compatible digital tapes from analog telemetry tapes. All data manipulations are very rigorously controlled. This equipment features:

1. A Universal time code translation system.
2. Fully automatic tape search and control operation.
3. Extremely versatile computer tape formatting.
4. Extensive built-in confidence testing.
5. Design for growth distribution center.

The analog-to-digital converter used in this system is the ASTRODATA Model TD-1003. This unit incorporates a sample-and-hold circuit with a sampling aperture of less than one microsecond. Digital output is in the form of polarity plus three decimal digits. Digitizing rate is 2.2 microseconds per decision. Recorded data may be accompanied with range time annotations to microsecond resolution. A built-in .01% calibration reference combined with an adjustable digital comparator provides extensive self-test capabilities.







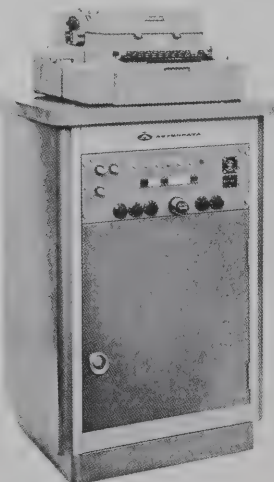
#### **AUTOMATIC HIGH-SPEED DIGITAL DATA ACQUISITION AND PROCESSING SYSTEM**

This system, designed and constructed for Lockheed Aircraft Corporation Missiles and Space Division, affords the maximum possible accuracy and reliability provided by the state of the art.

Various information signals are recorded in either digital or analog form. Two hundred channels of information from any of three sources are handled by this system. These sources are strain gage bridge signals, thermocouple signals and miscellaneous millivolt signals. The system will patch any combination of these three types of signals up to a maximum of 100 channels for any one type of signal. Provisions are included for the simultaneous and parallel analog recording of two 14-track magnetic tape recorders and two 50-channel recording oscillographs. In addition, there is a bar-graph type presentation on an oscilloscope for quick-look purposes. Accuracy of the digital recording system is  $\pm 0.1\%$  of full scale  $\pm \frac{1}{2}$  least significant digit. This system will record up to 10,000 samples-per-second on magnetic tape.

Editing facilities are provided to transcribe the initial magnetic tape recording into a format acceptable to either the IBM 704 or 709 computer. These editing facilities enable all or any section of the initially recorded magnetic tape to be transcribed into computer format or presented on the analog plotters. This editing process in no way damages the original tape. The multiplexer used in this system is a high-speed switching commutator consisting of individual chopper-type relays for each input channel. The switches connect one input channel at a time to the system's low-level amplifier. Output from the amplifiers is commutated to the analog-to-digital converter by transistor switches.

The buffer Register, a 16-bit storage register, stores each digital reading and transfers it to magnetic tape. The Buffer Register has two modes of operation. Initially, it accepts parallel information from the digital multiplexer and transfers it to the Raw Data Tape Recorder. Secondly, it receives information from the Raw Data Tape Recorder and transfers this information, four bits at a time, to the Computer Tape Recorder.

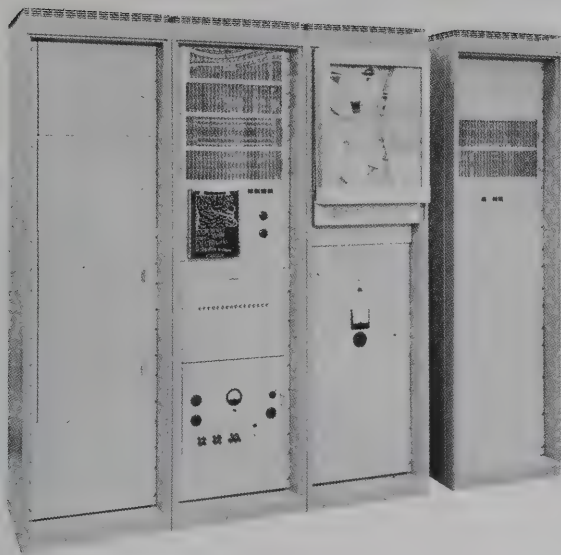


#### **THE AUTOMATIC DIGITAL TEMPERATURE RECORDING SYSTEM**

The primary function of this temperature recording system is to log, in "real" quantities, thermocouple temperature data from a nuclear process. The system accepts the output from thermocouples via a stepping switch scanner and master programmer. It automatically checks the thermocouple leads for continuity, filters and amplifies the incoming thermocouple voltage signals, measures and linearizes the thermocouple voltage to produce a digital number representing temperature. This number is then put into proper code to drive a Flexowriter typewriter/punch. The system consists of a continuity tester, thermocouple bridge with cold-junction compensation, low pass filter, differential amplifier, digital voltmeter, decimal-to-Flexowriter decoding network, buffer storage unit and associated log relay circuitry.

Unique in the circuitry is a modified ASTRODATA digital voltmeter which takes the output emf from the thermocouple after it has passed through a filter and dc amplifier, and linearizes the signal. Accuracy of the system is  $\pm 1^\circ\text{C}$  as determined by a calibrated thermocouple reference.





### THE 30-CHANNEL DIGITAL DATA RECORDING SYSTEM

This ultra-stable, highly precise (0.02% relative) data acquisition and recording system was designed by ASTRODATA for the Bell Telephone Laboratories to be used at the Western Electric Company facilities on the White Sands Missile Range. It is a multi-channel device designed to convert analog functions into binary-coded decimal values. These values are then recorded on a magnetic tape in a format compatible with IBM 704 series electronic data processing machines. Complete error-checking facilities are provided to check the data instrumentation system and the magnetic tape it produces. The system accepts 30 analog functions and two time inputs and processes them at a rate of 10 samples per-channel-per-second. This sampling rate can be increased on any channel or channels in ten-sample-per-second increments until a maximum system rate of 1,000 samples per second is obtained.

This system has a resolution of 15 binary digits: a sign bit plus 14 bits for the measured signals, which represents 32,768 bits full scale. The input signals are derived from a special-purpose, extremely precise analog computer that is used to process data originating in a high precision tracking radar. The original specification called for a conversion accuracy of  $\pm 0.1\%$  full scale; the Acceptance Tests showed a conversion accuracy of  $\pm 0.006\%$  of full scale.

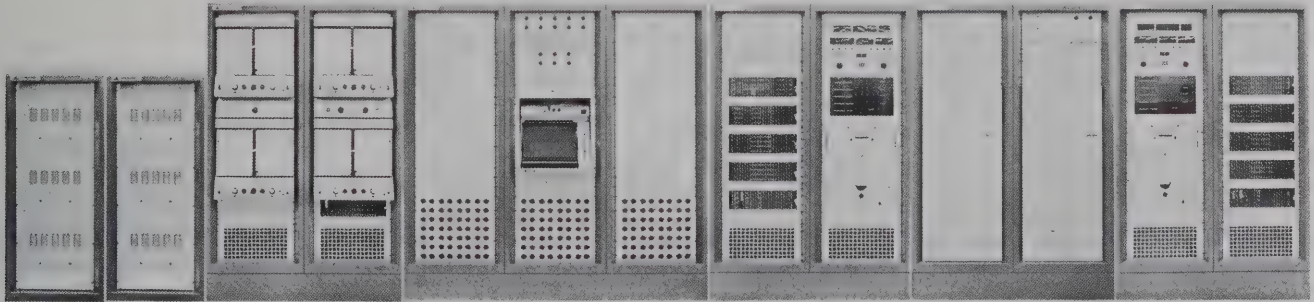
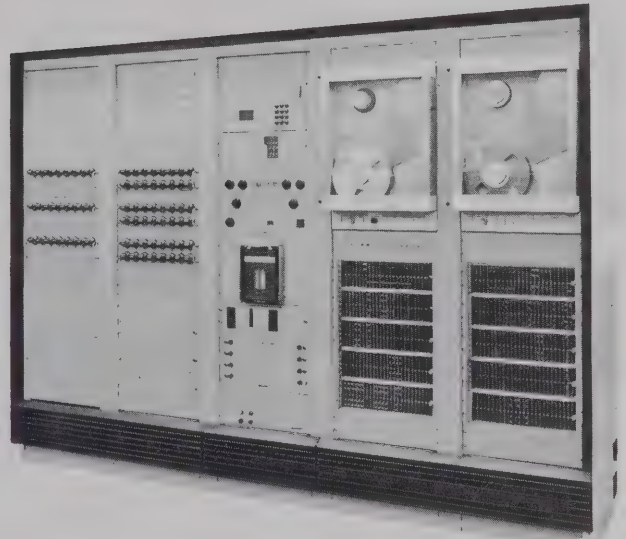
### ANALOG-TO-DIGITAL DATA HANDLING SYSTEM

This system is designed to acquire, condition, process, store and read out data that originates from tests conducted on missile components, assemblies and systems. It consists entirely of solid-state components with the exception of a minimum required number of vacuum tubes in the sample-and-hold circuitry and in the tape transport. Forty-eight channels of simultaneously generated high-level voltage (analog data) signals can be commutated. These signals are converted from the analog to the digital domain at high sampling rates. In addition, a time channel and a reference voltage channel are commutated. The analog-to-digital converter will handle up to 10,000 samples in one second. Data is recorded on an AMPEX FR-400 tape recorder called the storage or memory unit.

Data from the memory tape unit is played back into the file-tape unit (another AMPEX FR-400) to produce a gapped tape, the format of which is compatible and optimum for entry into an IBM 704 computer.

Any two channels of data may be selected from the magnetic tape recorder on either the memory or file-tape unit. These channels are converted back into the analog realm by a two-channel digital-to-analog converter. The analog signals may be displayed on a X-Y plotter or a two-pen recorder. They are also available for direct measurement as a check of the system. Any two of the digitized channels can be selected for conversion and plotting.

The system may be readily expanded to handle 100 channels. Additional space has been allowed in the cabinet and the original component arrangement is such that expansion can easily be accomplished in the field. The absolute over-all accuracy of the analog-to-digital conversion system is  $\pm 0.1\%$  of full scale;  $\pm \frac{1}{2}$  count of the least significant digit. This precision is maintained for all specified sampling rates up to and including 10,000 samples-per-second.



### THE LOW-SPEED DATA RECORDING AND PLOTTING SYSTEM

The Low-Speed Data Recording and Plotting System was designed and fabricated by ASTRODATA for the Missiles and Space Division of Lockheed Aircraft Corporation. The function of this system is to record data received from copper-constantan thermocouples or from other transducers that provide low-level dc millivolt signals.

The system consists of an analog input section, a digital data recording section, a plotting section and an analog recording section.

The analog input section is capable of receiving the input signals of 500 channels. These signals are routed through the analog input section to the digital data recording section and/or the analog recording section. The digital data recording section converts the analog information into digital form, whereupon it is recorded on punched cards and on paper tape. The

data recorded on the punched cards can be sorted and submitted to the plotting section. The analog recording section, using strip-chart recorders, monitors selected channels.

Both the signal and the return wiring of all analog voltages are shielded from the rest of the system, ensuring a high degree of isolation between the analog wiring and the rest of the equipment. This condition reduces the effect of common-mode voltage.

The system achieved a common-mode voltage-rejection ratio that exceeds 143-db at 60 cps and 169-db at dc.

The system features a digital linearizer — a device that converts the millivolt output copper-constantan thermocouples into degrees Fahrenheit. The conversion accuracy of this operation is  $\pm 3$  microvolts from 300°F to 400°F.





**ASTRODATA INC.**

*240 East Palais Road, Anaheim, California*



**ASTRODATA***discontinued  
2-64*

# MODEL 885-105 WIDEBAND DIFFERENTIAL DC AMPLIFIER

**bulletin**

630603

*885-223  
is new model  
about same as  
old one*

*2-64**\$830**fits**9006-103**rack*

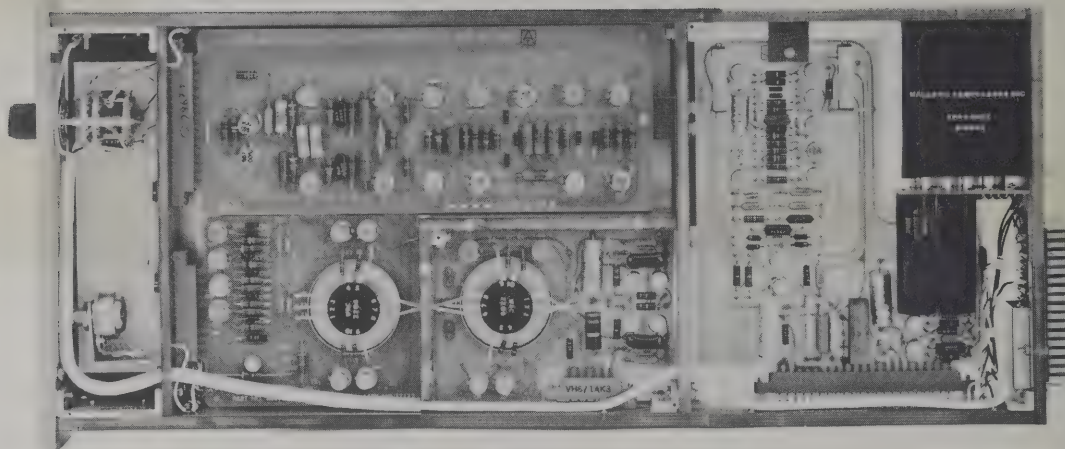
The ASTRODATA Model 885-105 is a high-performance, all solid-state differential dc amplifier which features fast settling time, low drift, low noise, wide bandwidth and extreme reliability. No mechanical choppers or relays are used. Newly developed field-effect transistors are used in the chopper circuit permitting low drift rates previously attainable only with mechanical choppers.

The input circuit is floating and guarded and is isolated from the output and power ground circuits. The output is also isolated from the input and power ground circuits. Each amplifier has its own internal power supply. Common mode rejection of 140 db at dc and 120 db to 60 cps is achieved with up to 1000 ohms source resistance unbalance in either input lead. Common mode voltages may be as great as  $\pm 300$  volts dc or peak ac.

Because the Model 885-105 uses a floating, guarded input circuit it may be used in applications where the source is floating from the output (as with a floating strain gauge circuit or when working into a galvanometer recorder). A dc return path from the load to the input through the ground circuit is not required when

connecting up this amplifier. Importantly, however, it works equally well in applications involving the use of thermocouples, resistance bridges, potentiometers, and other low-level or medium-level transducers. Its fast settling time, wide bandwidth and low output impedance make the Model 885-105 particularly attractive for use in both low-level multiplexed and high-level multiplexed data gathering systems, as well as in one-amplifier-per-channel systems where fast transients must be faithfully amplified to high levels for recording purposes.

Extremely compact, the Model 885-105 Amplifier measures only 1.6 inches wide by 8.75 inches high by 19 inches deep. Ten amplifiers mount in a standard rack-mounting unit occupying only 8.75 inches of vertical panel height. The very low power dissipation of 5 watts per unit eliminates the need for forced air ventilation throughout the ambient temperature range of 0° to 50°C. All circuits are mounted on plug-in etched-wiring circuit cards. Front panel controls include a gain switch, a continuously variable gain control and a screw-driver adjustment zero control.



Model 885-105

## SPECIFICATIONS

|                                           |                                                                                                                                                                                                                                                                                                                                |                                                                    |                                                                                                                                                 |
|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Voltage Gain Range:</b>                | Switch selected steps of 10, 20, 50, 100, 200, 500 and 1000; continuously variable between steps.                                                                                                                                                                                                                              | <b>Chopper Intermodulation:</b>                                    | Less than 0.1% dc to 1 kc                                                                                                                       |
| <b>Gain Accuracy:</b>                     | $\pm 0.1\%$ dc to 1 kc at 25°C.                                                                                                                                                                                                                                                                                                | <b>Frequency Response:</b>                                         | Down less than 3 db at 10 kc                                                                                                                    |
| <b>Linearity:</b>                         | $\pm 0.05\%$ of full scale output (10 volts) dc to 1 kc.                                                                                                                                                                                                                                                                       | <b>Settling Time:</b>                                              | 250 $\mu$ sec to within 0.1% of final value (either polarity).                                                                                  |
| <b>Gain Stability (1000 hours):</b>       | $\pm 0.1\%$ dc to 1 kc at 25°C                                                                                                                                                                                                                                                                                                 | <b>Isolation between Input and Output or Input and Case:</b>       | 1000 megohms at 60 cps, essentially infinite at dc.                                                                                             |
| <b>Input Impedance:</b>                   | Greater than 10 megohms shunted by less than 300 pf                                                                                                                                                                                                                                                                            | <b>Capacitance between Amplifier Input Circuit and Power Line:</b> | Less than 1.0 pf.                                                                                                                               |
| <b>Output Voltage:</b>                    | $\pm 10$ volts                                                                                                                                                                                                                                                                                                                 | <b>Common Mode Balance Controls:</b>                               | None                                                                                                                                            |
| <b>Output Current:</b>                    | $\pm 10$ ma                                                                                                                                                                                                                                                                                                                    | <b>Common Mode Rejection:</b>                                      | Greater than 140 db at dc, 120 db at 60 cps, 100 db at 400 cps for 1000 ohms or less of source resistance unbalance.                            |
| <b>Output Impedance:</b>                  | Less than 1.0 ohm in series with 50 $\mu$ h                                                                                                                                                                                                                                                                                    | <b>Common Mode Level:</b>                                          | $\pm 300$ volts dc or peak ac                                                                                                                   |
| <b>Rated Load:</b>                        | 1000 ohms minimum in parallel with 0.1 $\mu$ f maximum                                                                                                                                                                                                                                                                         | <b>Crosstalk in Model 9006 Rack Adapter:</b>                       | Maximum is less than noise level.                                                                                                               |
| <b>Short Circuit Protection:</b>          | Sustained output short circuit will not damage amplifier.                                                                                                                                                                                                                                                                      | <b>Amplifier Power:</b>                                            | 117 volts $\pm 10\%$ , 50 to 420 cps, 5 watts                                                                                                   |
| <b>Drift — 40 hours:</b>                  | $\pm 2$ microvolts referred to the input plus $\pm 0.5$ millivolts referred to the output at 25°C.                                                                                                                                                                                                                             | <b>Dimensions:</b>                                                 | 8.75 inches high by 1.6 inches wide by 19.0 inches deep                                                                                         |
| <b>Temperature Coefficient of Offset:</b> | $\pm 0.4$ $\mu$ V/°C referred to input plus $\pm 0.1$ mv referred to output from 0° to 50°C.                                                                                                                                                                                                                                   | <b>Model 9006 Rack Adapter:</b>                                    | Holds 10 amplifiers in standard 19-inch relay rack. Dimensions 8.75 inches high by 21.4 inches deep. Includes mating connectors for amplifiers. |
| <b>Noise:</b>                             | Less than 2 microvolts peak-to-peak referred to the input plus 40 microvolts peak-to-peak referred to the output (99% confidence) from 0.05 to 20 cps. Less than 3.5 microvolts rms referred to the input plus 350 microvolts rms referred to the output from 0.05 cps to 10 kc (source resistance 1000 ohms or less) at 25°C. |                                                                    |                                                                                                                                                 |



**ASTRODATA INC.**

240 EAST PALAIS ROAD • ANAHEIM, CALIFORNIA • PHONE (714) 772-1000

Litho in U.S.A.



**ASTRODATA**



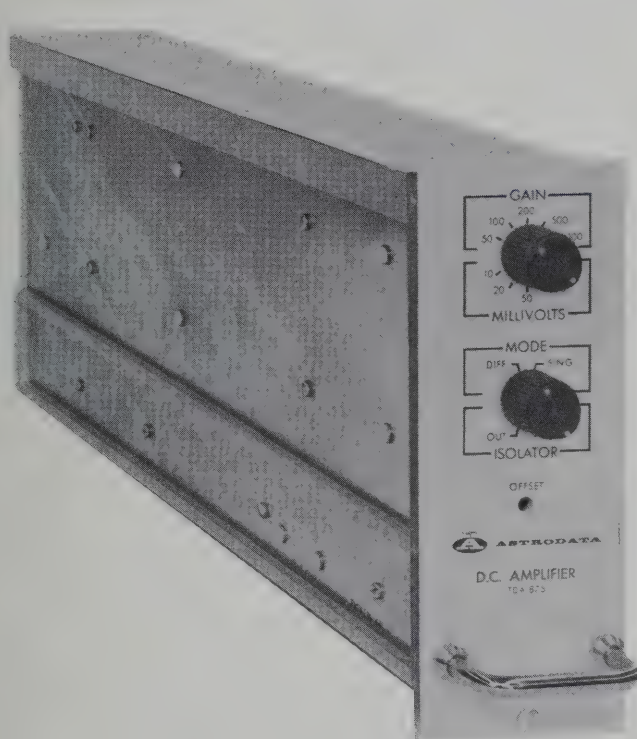
# SOLID STATE DIFFERENTIAL AND FLOATING WIDEBAND D C AMPLIFIERS

MODELS TDA-874 AND TDA-875

**bulletin**

621007

\$1295  
↓



Model TDA-875  
Dual-Mode Amplifier



Model TDA-874 Floating  
Amplifier in TDA-870A Portable Cabinet

designed specifically for use in applications where fast overload recovery, high common mode rejection, extraordinarily high input impedance and the ultimate in reliability are essential.

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# features

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- CHOICE OF FAST OVERLOAD RECOVERY CIRCUITS
- 1000 MEGOHMS INPUT TO OUTPUT ISOLATION AT 60 cps
- 100 MEGOHMS INPUT RESISTANCE
- 140 db COMMON MODE REJECTION AT dc
- 300 VOLTS COMMON MODE LEVEL RANGE
- DIFFERENTIAL OR FLOATING INPUT MODES
- BANDWIDTH UNAFFECTED BY GAIN SETTING
- DRIFT LESS THAN 2 MICROVOLTS PER WEEK
- NOISE LESS THAN 2 MICROVOLTS dc TO 20 cps
- ENTIRELY SOLID-STATE
- BUILT-IN POWER SUPPLY
- OUTPUT CLAMPED AT  $\pm 13$  VOLTS
- UNCONDITIONALLY SHORT-CIRCUIT PROOF

## GENERAL DESCRIPTION

The ASTRODATA Models TDA-874 and TDA-875 are solid-state potentiometric amplifiers which offer the ultimate in performance for applications involving amplification of thermocouple, strain gauge, or other low-level signals, low- or high-level multiplexing, precision analog-to-digital conversion or analog recording.

The Model TDA-875 offers both differential and wideband, floating modes of operation, and has a front panel switch to select the desired mode. For differential amplifier operation, it uses a dc-to-dc isolator to isolate the input circuit from the output circuit. The Model TDA-874 omits the isolator and offers only the wideband, floating, single-ended mode of operation.

The performance specifications for the TDA-874 and for the TDA-875 in the floating mode are identical. In the differential mode, the small transducer signals applied to the input terminals are accurately amplified while large common-mode signals which appear between the input terminals and power or case ground are rejected. Input terminals are isolated from output terminals and from case or power ground by at least 1000 megohms at 60 cps. Both output terminals are isolated from the input and from case or power ground. Either output terminal may be grounded or both may be left floating. The output is supplied from a passive filter which removes the high frequency isolator carrier from the signal.

In the floating mode, one input lead is common to

one output lead, but all input and all output leads are still isolated and shielded from case or power ground by at least 1000 megohms at 60 cps. This mode offers higher bandwidth, shorter settling time and larger output currents when working into isolated loads such as galvanometers. Because of the floating configuration, high rejection of common mode voltages appearing between transducers and power, or case grounds, can still be achieved. Phase of the input signal is not reversed in the floating mode.

Both modes offer an input resistance of at least 100 megohms. This unusually high value ensures that the entire transducer voltage will arrive intact at the amplifier. Changes in transducer or input line resistance unbalance have little effect on amplifier performance. Specifications listed for common mode rejection apply to transducer and line unbalances of 1000 ohms. At smaller values the common mode rejection is improved.

Of great importance to modern instrumentation systems is the fast overload recovery provided in both modes of operation. Accidental application of overload to the amplifier input can often be unavoidable, especially in low-level multiplexed systems where the amplifier may be switched to an open line or transducer. Recovery from 500% overload in 300 microseconds in the differential mode and in 125 microseconds in the floating mode ensures that accurate measurements will be made when the amplifier is switched subsequently to the next chan-



# SPECIFICATIONS

## Model TDA-875 (Floating, Single-ended Mode) and Model TDA-874

|                                    |                                                                                                                      |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Voltage Gain:                      | Fixed steps of 1000, 500, 200, 100 and 50.<br>See Modifications B, C and E for variable gain and other gain options. |
| Gain Accuracy:                     | $\pm 0.1\%$ dc to 1 kc into open circuit, at 25°C. See Modification D for other gain accuracy option.                |
| Linearity:                         | $\pm 0.01\%$ dc to 1 kc.                                                                                             |
| Gain Stability:                    | $\pm 0.01\%$ dc to 100~ for six months, at 25°C.                                                                     |
| Input Impedance:                   | Greater than 100 megohms shunted by 0.0007 microfarad.                                                               |
| Output Voltage:                    | $\pm 10$ volts, limited at less than $\pm 13$ volts, dc to 10 kc.                                                    |
| Output Current:                    | $\pm 50$ milliamperes, dc to 10 kc.                                                                                  |
| Output Impedance:                  | Less than 1 ohm in series with 50 microhenries.                                                                      |
| Rated Load Resistance:             | 200 ohms.                                                                                                            |
| Maximum Load Capacitance:          | 0.02 microfarad.                                                                                                     |
| Short-Circuit Protection:          | Sustained output short-circuit will not damage amplifier.                                                            |
| Drift — 40 Hours:                  | $\pm 2$ microvolts referred to the input (at 25°C).                                                                  |
| Drift — Six Months:                | $\pm 4$ microvolts referred to the input (at 25°C).                                                                  |
| Temperature Coefficient of Offset: | $\pm 0.5$ microvolt per °C. referred to the input.                                                                   |

## Zero Adjustment Range:

Adjustable to less than 0.01% of full-scale output on any range. Nominal adjustment range is  $\pm 20$  microvolts referred to the input at gain of 1000.

## Noise:

Less than 2 microvolts peak-to-peak referred to the input, plus 40 microvolts peak-to-peak referred to the output (99% confidence) from 0.05 to 20 cps. Less than 5 microvolts rms referred to the input plus 150 microvolts rms referred to the output from 0.05 cps to 30 kc. (Source resistance 1000 ohms or less), at 25°C.

## Chopper Intermodulation:

Less than  $\pm 0.1\%$  dc to 1 kc.

## Frequency Response:

$\pm 0.1$  db dc to 10 kc, down 3 db at 150 kc.

## Settling Time:

35 microseconds to within 1% of final value (either polarity) on all ranges.

## Overload Recovery Time:

125 microseconds or less to within 1% of final value from up to 500% overload.  
See Modification A for other overload recovery option.

## Isolation Between Input and Case or Output and Case:

1000 megohms at 60 cps, essentially infinite at dc.

## \*Available Modifications (TDA-874 or TDA-875 in Floating Mode)

### Modification A:

Alters overload recovery to provide recovery from any input overload up to  $\pm 10$  volts for gains of 50 and above of 1 millisecond to within 100 microvolts of final value referred to the input. In addition, the following specifications are changed:

- (1) Output voltage is not limited at less than  $\pm 13$  volts.
- (2) Gain accuracy at 10 kc is  $\pm 5\%$ .
- (3) Noise from 0.05 cps to 30 kc is 7 microvolts rms referred to the input plus 150 microvolts rms referred to the output.
- (4) Input resistance is 10 megohms.
- (5) Input resistance is 470 ohms while the amplifier is overloaded.

### Modification B:

Substitutes single fixed-gain of any value between 1 and 5000. Specify Modification B and the gain value desired.

At gains less than 50 the following specifications are changed:

- (1) Noise from 0.05 cps to 30 kc is 350 microvolts rms referred to the output.
- (2) Drift for 40 hours is  $\pm 100$  microvolts referred to the output; for six months it is  $\pm 200$  microvolts referred to the output.
- (3) Temperature coefficient of offset is  $\pm 50$  microvolts referred to the output per °C.
- (4) Fast overload recovery may not be provided. Consult manufacturer for details.

At gains greater than 1000 the following specifications are changed:

- (1) Frequency response is inversely proportional to gain, e.g., at a

gain of 2000 the frequency response is down 3 db at 75 kc.

- (2) Settling time is directly proportional to gain, e.g., at a gain of 2000 the settling time is 50 microseconds to within 1% of final value.

### Modification C:

Adds continuously variable gain control adjustable upwards at least  $2\frac{1}{2}$  to 1 from gain steps shown. Gain accuracy with control fully counter-clockwise is within  $\pm 0.2\%$  of the gain step selected. Linearity of the variable gain control is  $\pm 0.1\%$ . In addition, the following specifications are changed:

- (1) Frequency response is inversely proportional to the setting of the variable gain control, e.g., when it is set maximum clockwise (gain  $2\frac{1}{2}$  times the gain step selected) the frequency response is down 3 db at about 60 kc.
- (2) Settling time is directly proportional to the setting of the variable gain control, e.g., when it is set maximum clockwise the settling time is about 63 microseconds to within 1% of final value.

### Modification D:

Initial dc gain accuracy is improved up to  $\pm 0.001\%$  in the floating mode. Specify Modification D and the gain accuracy desired. Gain stability is  $\pm 0.01\%$  dc to 100~ for six months.

### Modification E:

Provides additional gain steps in the range from 1 to 5000. A total number of 11 gain steps may be specified. The specification changes listed under Modification B in the floating mode for gains less than 50 or greater than 1000 also apply to this modification.

### Modification F:

Provides electrical readout of gain step selected. A single-pole contact closure is provided between a common wire and a wire corresponding to each gain step. Contact is rated at 1 ampere at up to  $\pm 48$  volts dc.

\*Certain combinations of modifications may result in overall performance other than that implied by this specification. Consult manufacturer for details.

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# features

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The ASTRODATA Models TDA-874 and TDA-875 are solid-state potentiometric amplifiers which offer the ultimate in performance for applications involving amplification of thermocouple, strain gauge, or other low-level signals, low- or high-level multiplexing, precision analog-to-digital conversion or analog recording.

The Model TDA-875 offers both differential and wideband, floating modes of operation, and has a front panel switch to select the desired mode. For differential amplifier operation, it uses a dc-to-dc isolator to isolate the input circuit from the output circuit. The Model TDA-874 omits the isolator and offers only the wideband, floating, single-ended mode of operation.

The performance specifications for the TDA-874 and for the TDA-875 in the floating mode are identical. In the differential mode, the small transducer signals applied to the input terminals are accurately amplified while large common-mode signals which appear between the input terminals and power or case ground are rejected. Input terminals are isolated from output terminals and from case or power ground by at least 1000 megohms at 60 cps. Both output terminals are isolated from the input and from case or power ground. Either output terminal may be grounded or both may be left floating. The output is supplied from a passive filter which removes the high frequency isolator carrier from the signal.

In the floating mode, one input lead is common to

one output lead, but all input and all output leads are still isolated and shielded from case or power ground by at least 1000 megohms at 60 cps. This mode offers higher bandwidth, shorter settling time and larger output currents when working into isolated loads such as galvanometers. Because of the floating configuration, high rejection of common mode voltages appearing between transducers and power, or case grounds, can still be achieved. Phase of the input signal is not reversed in the floating mode.

Both modes offer an input resistance of at least 100 megohms. This unusually high value ensures that the entire transducer voltage will arrive intact at the amplifier. Changes in transducer or input line resistance unbalance have little effect on amplifier performance. Specifications listed for common mode rejection apply to transducer and line unbalances of 1000 ohms. At smaller values the common mode rejection is improved.

Of great importance to modern instrumentation systems is the fast overload recovery provided in both modes of operation. Accidental application of overload to the amplifier input can often be unavoidable, especially in low-level multiplexed systems where the amplifier may be switched to an open line or transducer. Recovery from 500% overload in 300 microseconds in the differential mode and in 125 microseconds in the floating mode ensures that accurate measurements will be made when the amplifier is switched subsequently to the next chan-



# SPECIFICATIONS

## Model TDA-875 (Floating, Single-ended Mode) and Model TDA-874

|                                    |                                                                                                                      |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------|
| Voltage Gain:                      | Fixed steps of 1000, 500, 200, 100 and 50.<br>See Modifications B, C and E for variable gain and other gain options. |
| Gain Accuracy:                     | $\pm 0.1\%$ dc to 1 kc into open circuit, at 25°C. See Modification D for other gain accuracy option.                |
| Linearity:                         | $\pm 0.01\%$ dc to 1 kc.                                                                                             |
| Gain Stability:                    | $\pm 0.01\%$ dc to 100~ for six months, at 25°C.                                                                     |
| Input Impedance:                   | Greater than 100 megohms shunted by 0.0007 microfarad.                                                               |
| Output Voltage:                    | $\pm 10$ volts, limited at less than $\pm 13$ volts, dc to 10 kc.                                                    |
| Output Current:                    | $\pm 50$ milliamperes, dc to 10 kc.                                                                                  |
| Output Impedance:                  | Less than 1 ohm in series with 50 microhenries.                                                                      |
| Rated Load Resistance:             | 200 ohms.                                                                                                            |
| Maximum Load Capacitance:          | 0.02 microfarad.                                                                                                     |
| Short-Circuit Protection:          | Sustained output short-circuit will not damage amplifier.                                                            |
| Drift — 40 Hours:                  | $\pm 2$ microvolts referred to the input (at 25°C).                                                                  |
| Drift — Six Months:                | $\pm 4$ microvolts referred to the input (at 25°C).                                                                  |
| Temperature Coefficient of Offset: | $\pm 0.5$ microvolt per °C. referred to the input.                                                                   |

## Zero Adjustment Range:

Adjustable to less than 0.01% of full-scale output on any range. Nominal adjustment range is  $\pm 20$  microvolts referred to the input at gain of 1000.

## Noise:

Less than 2 microvolts peak-to-peak referred to the input, plus 40 microvolts peak-to-peak referred to the output (99% confidence) from 0.05 to 20 cps. Less than 5 microvolts rms referred to the input plus 150 microvolts rms referred to the output from 0.05 cps to 30 kc. (Source resistance 1000 ohms or less), at 25°C. Less than  $\pm 0.1\%$  dc to 1 kc.

## Chopper Intermodulation:

## Frequency Response:

$\pm 0.1$  db dc to 10 kc, down 3 db at 150 kc.

## Settling Time:

35 microseconds to within 1% of final value (either polarity) on all ranges.

## Overload Recovery Time:

125 microseconds or less to within 1% of final value from up to 500% overload. See Modification A for other overload recovery option.

## \*Available Modifications (TDA-874 or TDA-875 in Floating Mode)

|                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Modification A: | Alters overload recovery from any input to $\pm 10$ volts for gains of 100 or less to 1 millisecond to within 1% of final value referred to the input. In addition, the following modifications are changed:<br>(1) Output voltage less than $\pm 13$ volts.<br>(2) Gain accuracy $\pm 0.1\%$ .<br>(3) Noise from the input is 7 microvolts rms referred to the input.<br>(4) Input resistance less than 1 ohm.<br>(5) Input range $\pm 10$ volts while the input is less than $\pm 13$ volts. |
|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

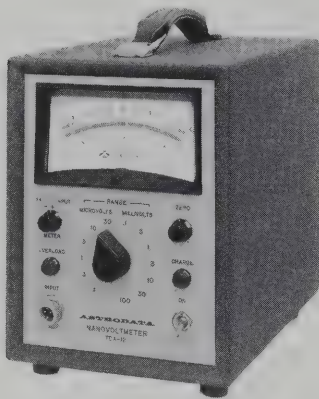
|                 |                                                                                                                                                                                                                                                    |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Modification B: | Substitutes a value between $\pm 10$ and $\pm 13$ volts for the desired output. At gain of 1000, the specified output is $\pm 10$ volts.<br>(1) Noise from the input is 7 microvolts rms referred to the input.<br>(2) Gain accuracy $\pm 0.1\%$ . |
|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

\*Certain combinations of modifications are available other than that implied for details.

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Other ASTRODATA amplifiers include:

Model TDA-874G — a low-level potentiometric amplifier intended for driving all popularly used galvanometers. The high input impedance, high input-to-ground isolation, wide bandwidth, fast settling time, low noise, low drift and excellent linearity common to other ASTRODATA amplifiers have been retained. Gain range is continuously adjustable from 0.5 to 5000, providing at least  $\pm 2$  inch deflection for most galvanometers. A built-in, continuously adjustable and calibrated damping resistor covers the range from 0 to 1000 ohms. A built-in current limiter assures protection against galvanometer burnout. The input circuit will withstand sustained 10-volt overloads and the output is short-circuit-proof. Full specifications contained in Bulletin 611003.



The ASTRODATA Model TDA-121 Nanovoltmeter is a completely transistorized instrument of extreme sensitivity offering a new concept in a meter designed to measure ultra-low dc voltages. Self-contained battery operation yields complete isolation of circuit from power ground to assure hum-free performance and freedom from ground-loop problems. Covering bi-polar center-zero dc ranges of 0.1 microvolt to 100 millivolts, the input resistance is at least 1 megohm on all ranges. Source resistance may vary from 0 to 2000 ohms. Noise is only 0.01 microvolts rms. Amplifier output is flat from dc to 100 cps (3 db point), delivers  $\pm 5$  volts at 10 milliamperes. Full specifications contained in Bulletin 620201.

The ASTRODATA Model TOA-110 is a high-performance, solid-state, chopper-stabilized operational amplifier in modular form intended for use in analog computer and data reduction systems. Gain is extremely high — at least 10 million at dc. A variable gain feature allows forward gain to be adjusted over a range of about 100 to 1 so that a bandwidth from dc to 250-kc may be obtained with a large variety of feedback configurations. Solid-state choppers are used throughout. Full specifications contained in Bulletin 611001.



**ASTRODATA**

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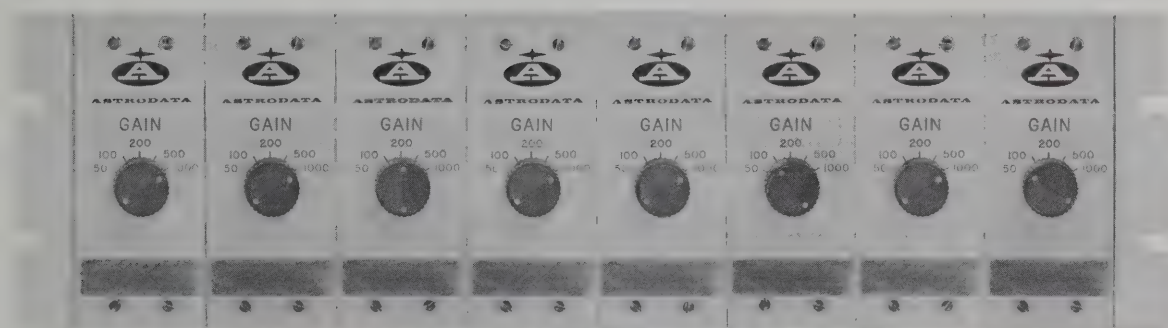
**ASTRODATA**



# MODEL TDA-880 DIFFERENTIAL AMPLIFIER

**bulletin**

520501



## GENERAL DESCRIPTION

The ASTRODATA Model TDA-880 is a high-performance differential dc amplifier designed especially for use with thermocouple, strain gauge, resistance bulb and other low-level transducers. It features extremely high common-mode rejection, low zero drift and low noise. Very high input resistance of at least 10 megohms assures negligible error due to transducer loading.

The small front panel area required by the amplifier makes it particularly attractive for multi-

channel system installations. The ASTRODATA Rack Mount accepts up to eight amplifiers and is only 5¼ inches high. Each amplifier is shielded to prevent interchannel crosstalk.

Several optional modifications are available to increase the usefulness of the amplifier in particular applications. These options include better gain accuracy, wider gain range, and a built-in filter which offers a one or two real-pole roll-off beginning at any of five frequencies selected by a front-panel switch.



## SPECIFICATIONS

|                                    |                                                                                                                                                                                                                                                                                                                   |                              |                                                                                                                                                                                                                                                                                                                                                            |
|------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Gain:</b>                       | Fixed steps of 50, 100, 200, 500 and 1000.                                                                                                                                                                                                                                                                        | <b>Noise at 25° C:</b>       | RMS value for 1000 ohms line unbalance in either input lead for zero to full scale input levels: 0.35 microvolts referred to the input plus 0.002% of full scale referred to the output in the band from 0.05 cps to 20 cps; 1.0 microvolt referred to the input plus 0.003% of full scale referred to the output in the band from 0.05 cps to 60,000 cps. |
| <b>Gain Accuracy at 25° C:</b>     | $\pm 0.1\%$ at dc, within 1 db to 80 cps, within 3 db to 200 cps.                                                                                                                                                                                                                                                 | <b>Input Resistance:</b>     | Greater than 10 megohms.                                                                                                                                                                                                                                                                                                                                   |
| <b>Gain Stability at 25° C:</b>    | $\pm 0.02\%$ for three months.                                                                                                                                                                                                                                                                                    | <b>Output Voltage:</b>       | 0 to $\pm 5$ volts dc or peak ac.                                                                                                                                                                                                                                                                                                                          |
| <b>DC Linearity:</b>               | $\pm 0.02\%$ of 5 volts full scale output.                                                                                                                                                                                                                                                                        | <b>Output Current:</b>       | All specifications apply for output loads of 0 to $\pm 10$ milliamperes.                                                                                                                                                                                                                                                                                   |
| <b>Common Mode Rejection:</b>      | 140 db at dc, 120 db at 60 cps for up to 1000 ohms unbalance in either input lead.                                                                                                                                                                                                                                | <b>Output Resistance:</b>    | Less than 1.0 ohm.                                                                                                                                                                                                                                                                                                                                         |
| <b>Common Mode Voltage:</b>        | $\pm 300$ volts dc or peak ac.                                                                                                                                                                                                                                                                                    | <b>Temperature Range:</b>    | 0 to $+40^\circ$ C.                                                                                                                                                                                                                                                                                                                                        |
| <b>Zero Offset at 25° C:</b>       | $\pm 1$ microvolt referred to the input plus $\pm 0.02\%$ of full scale referred to the output with input shorted. Offset increases 0.5 microvolt referred to the input with each 1000 ohms increase in input source resistance.                                                                                  | <b>Power Requirements:</b>   | Any one of the following power supplies or equivalent:<br>Model PC88A — supplies 1 amplifier;<br>Model 2010 — supplies up to 14 amplifiers;<br>Model 2011 — supplies up to 80 amplifiers.                                                                                                                                                                  |
| <b>Zero Offset Drift at 25° C:</b> | Over a three-months period, for all ranges and with input shorted and at constant temperature: $\pm 2$ microvolts referred to the input plus $\pm 0.02\%$ of full scale referred to the output. Offset drift increases 1 microvolt referred to the input with each 1000 ohms increase in input source resistance. | <b>Power Dissipated:</b>     | 4.0 watts maximum.                                                                                                                                                                                                                                                                                                                                         |
|                                    |                                                                                                                                                                                                                                                                                                                   | <b>Size:</b>                 | 2 $\frac{1}{8}$ -in wide by 5 $\frac{1}{4}$ -in high by 15 $\frac{1}{2}$ -in deep.                                                                                                                                                                                                                                                                         |
|                                    |                                                                                                                                                                                                                                                                                                                   | <b>Connector:</b>            | 31-pin etched circuit card connector.                                                                                                                                                                                                                                                                                                                      |
|                                    |                                                                                                                                                                                                                                                                                                                   | <b>Rack Mounting Module:</b> | Model RM88 Module holds up to 8 amplifiers in standard 19-in relay rack cabinet. Includes mating connectors for amplifiers. Size 5 $\frac{1}{4}$ -in high by 16 $\frac{1}{4}$ -in deep behind panel.                                                                                                                                                       |

### OPTIONAL MODIFICATIONS

- Modification E:** Substitutes other gain steps in place of the steps provided in the standard amplifier. Any five steps in the gain range from 50 to 5000 may be selected. Specify Modification E and the gain steps desired.
- Modification J:** Any desired initial gain accuracy up to 0.02% can be supplied. Specify Modification J and the gain accuracy desired.
- Modification L:** Incorporates five built-in filters, each with two real poles to provide 12 db per octave roll-off with cut-off frequencies (6-db points) at 2, 5, 10, 30 and 100 cps selected by a front-panel switch.
- Modification L-a:** Substitutes other roll-off frequencies in place of those in Modification L and allows the two poles to be at different frequencies. One pole can be as low as 0.25 cps, while the other can be as low as 2 cps. Specify Modification L-a and pole frequencies desired.
- Modification M:** Provides screwdriver adjustment at the front panel for zeroing amplifier output for any condition of drift within the operating temperature range.



**ASTRODATA INC.**

240 East Palms Road, Anaheim, California



**ASTRODATA**



# MODEL TDA-874G AMPLIFIER

**bulletin**

611003



## **A Low-Level Potentiometric Amplifier to Drive Galvanometers**

### **GENERAL DESCRIPTION**

The ASTRODATA Model TDA-874G is a low-level potentiometric amplifier intended for driving all popularly-used galvanometers. The Model TDA-874G permits saving of time and money by preventing repetitious replacement of burned-out galvanometer movements and the troublesome installation of damping and calibration resistors each time a test set-up is changed. All of the desirable

features found in other ASTRODATA amplifiers, notably high input-to-ground isolation, wide bandwidth, high input impedance, fast settling time, low noise, low drift and excellent linearity, are also offered in the Model TDA-874G.

Gain range is continuously adjustable from 0.5 to 5000, providing at least  $\pm 2$ -inch deflection for all galvanometers except a few of the least sensitive fluid-damped types. These latter types are deflected

at least  $\pm 1$  inch. A built-in, continuously adjustable and calibrated damping resistor covers the range from 0 to 1000 ohms.

A built-in current limiter has two ranges: limited sharply at  $\pm 100$  ma, but linear from 0 to  $\pm 50$  ma for fluid-damped galvanometers, and limited at  $\pm 10$  ma but linear from 0 to  $\pm 5$  ma for magnetically damped galvanometers. This feature assures positive protection against galvanometer burnout regardless of the conditions of input overload or in case of incorrect damping resistor setting.

The floating potentiometric circuit will withstand sustained 10-volt input overloads on any range and the output is unconditionally short-circuit-proof. Isolation of 10,000 megohms at dc and greater than 1000 megohms at 60 cps from power or case grounds makes possible common mode rejection of 140 db at dc and 100 to 120 db at 60 cps when working into floating galvanometer loads, even with unbalanced transducer or input wiring resistance. Common mode voltages can be as great as  $\pm 300$  volts dc or 117 rms ac.

## SPECIFICATIONS

|                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Voltage Gain Range:</b>                | 0.5 to 5000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   | <b>Noise:</b>                                                    | Less than 2 microvolts peak-to-peak referred to the input, plus 40 microvolts peak-to-peak referred to the output (99% confidence) from 0.05 to 20 cps. Less than 5 microvolts rms referred to the input, plus 150 microvolts rms referred to the output from 0.05 cps to 30 kc.                                                                                                                                                                                                                                                     |
| <b>Fixed Steps:</b>                       | 50, 100, 200, 500, 1000, 2000                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Chopper Intermodulation:</b>                                  | Less than 0.1% dc to 1 kc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Variable Control:</b>                  | Upwards $2\frac{1}{2}$ to 1 from fixed steps.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Frequency Response:</b>                                       | $\pm 1\%$ dc to 10 kc, down 3 db at 150 kc with variable gain control set counterclockwise except on fixed gain step of 2000. If fixed gain step is 2000 and attenuator is set to either x1.0 or x0.01 (total gain = 2000 or 20) response is $\pm 1\%$ dc to 5 kc, down 3 db at 75 kc. At other positions of the variable gain control, the bandwidth is inversely proportional to control setting, and is approximately $2\frac{1}{2}$ times less than the above figures when the control is set to the maximum clockwise position. |
| <b>Attenuator Steps:</b>                  | x1.0 and x0.01                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Settling Time:</b>                                            | 25 microseconds to within 1% of final value with variable control set counterclockwise except on fixed gain step of 2000. If fixed gain step is 2000 and attenuator set to either x1.0 or x0.01 (total gain = 2000 or 20) settling time is 50 microseconds. At other settings of the variable gain control the settling time is proportional to control setting, and is approximately $2\frac{1}{2}$ times longer than the above figures when the control is set to the maximum clockwise position.                                  |
| <b>Gain Accuracy:</b>                     | $\pm 0.2\%$ at dc with gain potentiometer counter-clockwise into open circuit.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Isolation Between Input and Case:</b>                         | 1000 megohms at 60 cps; essentially infinite at dc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Gain Stability:</b>                    | $\pm 0.15\%$ at dc with gain potentiometer counter-clockwise.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 | <b>Crosstalk in Model TDA-870 Rack:</b>                          | Maximum is less than noise level.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |
| <b>Linearity:</b>                         | $\pm 0.01\%$ of full-scale output (10 volts) dc to 1 kc.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <b>Amplifier Power:</b>                                          | 117 volts $\pm 10\%$ , 50-400 cps, 15 watts.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Input Impedance:</b>                   | Greater than 100 megohms shunted by 0.0007 microfarad.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | <b>Dimensions:</b>                                               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Output Characteristics</b>             | <p>Limit 100 ma, Attenuator 1:<br/>Output voltage <math>\pm 10</math> volts into open circuit.</p> <p>Output current <math>\pm \left[ \frac{10,000}{140 + R_D + R_G} \right]</math> ma,<br/>limited at <math>\pm 100</math> ma into short circuit.</p> <p>Limit 10 ma Attenuator 1:<br/>Output voltage <math>\pm 7.5</math> volts into open circuit.</p> <p>Output current <math>\pm \left[ \frac{7500}{1100 + R_D + R_G} \right]</math> ma<br/>limited at <math>\pm 10</math> ma into short circuit.</p> <p>Limit 10 ma, Attenuator 100:1:<br/>Output voltage <math>\pm 0.1</math> volts into open circuit.</p> <p>Output current <math>\pm \left[ \frac{100}{2 + R_G + R_D} \right]</math> ma,<br/>limited at <math>\pm 10</math> ma into 11 ohms or greater.</p> <p><math>R_D</math> = Damping Resistance (ohms)<br/><math>R_G</math> = Galvanometer Resistance (ohms)</p> | <b>Model TDA-874-G Amplifier:</b>                                | 8.1 in. high x 3.2 in. wide x 19.4 in. deep.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Output Impedance:</b>                  | Less than 2 ohms in series with damping resistor.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Model TDA-870 Rack Mounting Adapter: (holds 5 amplifiers)</b> | 8.75 in. high x 21 in. deep including connectors. Fits standard 19 in. rack.                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
| <b>Damping Resistor Range:</b>            | 0 to 1000 ohms.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               | <b>Model TDA-870A Portable Cabinet:</b>                          | 10.75 in. high x 4.25 in. wide x 22.1 in. deep.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Damping Resistor Resolution:</b>       | $\pm 0.2$ ohm.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>Finish:</b>                                                   |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
| <b>Short Circuit Protection:</b>          | Sustained output short circuit will not damage amplifier.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Panel Background:</b>                                         | Smooth, Federal Std. 595, Color 34058 (dark green).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Drift — 40 hours:</b>                  | $\pm 2$ microvolts referred to the input.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Panel Lettering:</b>                                          | Silk Screen, Federal Std. 595, Color 37875 (white).                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
| <b>Drift — 6 months:</b>                  | $\pm 4$ microvolts referred to the input.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | <b>Portable Cabinet:</b>                                         | Leatherette, Federal Std. 595, Color 34058 (dark green).                                                                                                                                                                                                                                                                                                                                                                                                                                                                             |
| <b>Temperature Coefficient of Offset:</b> | $\pm 0.5$ microvolt per $^{\circ}\text{C}$ referred to the input.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | <b>Weight: (Model TDA-874-G)</b>                                 | 14 pounds.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Zero Adjustment Range:</b>             | $\pm 20$ microvolts nominal referred to the input on gain of 1000.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                                                                  |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |



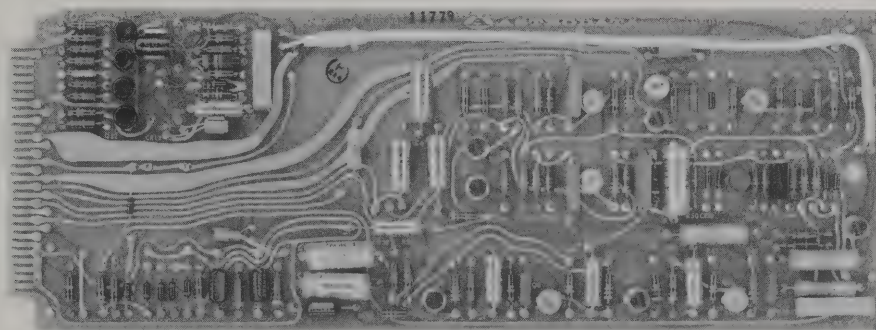
**ASTRODATA INC.**

240 East Palais Road, Anaheim, California



**ASTRODATA**

# MODEL TOA-110 TRANSISTORIZED OPERATIONAL AMPLIFIER

**bulletin****611001**

## DESCRIPTION

The Astrodata Model TOA-110 is a high-performance, solid-state, chopper-stabilized operational amplifier in modular form intended for use in analog computer and data reduction systems. It is a plug-in unit constructed on an etched circuit card.

Gain is extremely high, being at least 10 million at dc. An exclusive variable gain feature allows the forward gain to be adjusted over a range of about 100 to 1 so that a bandwidth from dc to 250-kc can be obtained with a large variety of feedback configurations. The adjustment is made by selecting the value of a resistor in the amplifier to match the characteristics of the feedback network. Solid-state choppers are used throughout.

Provisions have been made for mounting single input resistive or capacitive feedback networks on the amplifier card. The output and summing point are brought to pins on the circuit card connector for connection to more complex external feedback networks.

Large output signals (10 volts peak ac) can be delivered

from the amplifier at frequencies from dc to 5 kc. At higher frequencies the maximum peak output voltage available is inversely proportional to frequency. For small output signals, the frequency response is down 3 db at 250kc with unity gain.

The amplifier is stable and will not oscillate with any value of input or feedback resistor. The amplifier is also stable when connected as an integrator. Phase shift is approximately 90° over the frequency range of 0.1 cps to 500 kc. This arrangement optimizes closed loop transient response and dc gain accuracy in addition to providing adequate phase margin for stability against oscillation for a wide variety of feedback configurations.

A rack mounting unit, #7013-D-209, is available for mounting one to twenty-six amplifiers in a standard relay rack cabinet. The mounting unit contains the circuit card sockets which make connections to the amplifiers for input, output, power and feedback network. The only power requirements are  $\pm 18$  volts dc at 30 milliamperes per amplifier.

## AMPLIFIER CHARACTERISTICS (without feedback)

|                                               |                                                                                                                                                           |
|-----------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Type:                                         | Operational, single-ended.                                                                                                                                |
| Gain (open loop):                             | Adjustable from $10^6$ to $10^8$ .                                                                                                                        |
| Input Resistance:                             | 20,000 ohms, $\pm 25\%$ .                                                                                                                                 |
| Output Voltage:                               | Greater than $\pm 10$ volts dc or peak ac.                                                                                                                |
| Output Current:                               | Greater than $\pm 10$ milliamperes.                                                                                                                       |
| Voltage Offset:                               | Adjustable to zero.<br>nominal range = $\pm 1$ mv                                                                                                         |
| Voltage Offset Drift:                         | 6 $\mu\text{v}/\text{hour}$ ; 15 $\mu\text{v}/\text{day}$ ; 20 $\mu\text{v}/\text{week}$ ;<br>50 $\mu\text{v}/3$ months referred to the input<br>at 25°C. |
| Temperature Coefficient<br>of Voltage Offset: | 2 $\mu\text{v}/^\circ\text{C}$ (referred to input).                                                                                                       |
| Input Current Offset:                         | Adjustable to zero.<br>(nominal range = $\pm 10^{-9}$ amp.)                                                                                               |
| Input Current Offset<br>Drift:                | 0.6 $\times 10^{-10}$ amps/hour; 1.5 $\times 10^{-10}$<br>amps/day; 2 $\times 10^{-10}$ amps/week;<br>5 $\times 10^{-10}$ amps/3 months at 25°C.          |

Temperature Coefficient  
of Input Current Drift:  
Output Short Circuit  
Protection:  
Operating Temperature  
Range:

2  $\times 10^{-11}$  amps/ $^\circ\text{C}$ .

Size:

Power Requirements:

Mating Connector:

Rack Mount #7013-D-209:

A sustained short circuit at the output will not damage the unit. All specifications (except drift as noted) remain constant over the range from +5°C to +40°C. 4 3/8 in. high x 13 1/2 in. long x 1/2 in. thick circuit card.  $\pm 18$  volts  $\pm 5\%$  dc at 30 milliamperes. 31-pins; Kennedy Industries KI-1500-31 or equal. 5 1/4 in. high x 19 in. wide x 16 in. deep. Nylon card guides on 5/8 in. centers hold one to twenty-six amplifiers in frame for relay rack mounting. Includes wiring trough at rear of rack mount.

# AMPLIFIER CHARACTERISTICS (without feedback)

|                                                   |                                                                                                                                      |                                                        |                                                                                                                                                                                               |
|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Type:</b>                                      | Operational, single-ended.                                                                                                           | <b>Input Current Offset:</b>                           | 10 <sup>-9</sup> amps max.                                                                                                                                                                    |
| <b>Gain (open loop):</b>                          | Adjustable from 10 <sup>7</sup> to 2 x 10 <sup>9</sup> .                                                                             | <b>Temperature Coefficient of Input Current Drift:</b> | 2 x 10 <sup>-11</sup> amps/°C.                                                                                                                                                                |
| <b>Input Resistance:</b>                          | 100,000 ohms dc, 20,000 ohms ac (±25%).                                                                                              | <b>Output Short Circuit Protection:</b>                | A sustained short circuit at the output will not damage the unit.                                                                                                                             |
| <b>Output Voltage:</b>                            | Greater than ±10 volts dc or peak ac.                                                                                                | <b>Operating Temperature Range:</b>                    | All specifications (except drift as noted) remain constant over the range from +5°C to +40°C.                                                                                                 |
| <b>Output Current:</b>                            | Greater than ±10 milliamps.                                                                                                          | <b>Size:</b>                                           | 4½-in. high x 9-in. long x ½-in. thick circuit board.                                                                                                                                         |
| <b>Settling Time:</b>                             | Less than 12 μsec. to 0.01% of final value, full scale to full scale, less than 10 μsec. to 0.01% of final value full scale to zero. | <b>Power Requirements:</b>                             | ±18 volts ±5% dc at 40 milliamps.                                                                                                                                                             |
| <b>Noise:</b>                                     | Less than 100 μv rms from dc to 1 mc referred to summing point.                                                                      | <b>Mating Connector:</b>                               | 31-pins; Kennedy Industries, KI-1500-31 or equal.                                                                                                                                             |
| <b>Intermodulation Distortion:</b>                | Less than 0.05%.                                                                                                                     | <b>Rack Mount #7013-D-209:</b>                         | 5¼-in. high x 19-in. wide x 16-in. deep. Nylon card guides on ⅝-in. centers hold one to twenty-six amplifiers in frame for relay rack mounting. Includes wiring trough at rear of rack mount. |
| <b>Voltage Offset:</b>                            | Adjustable to zero; nominal range = ±1 mv.                                                                                           |                                                        |                                                                                                                                                                                               |
| <b>Voltage Offset Drift:</b>                      | 6 μv/hour; 15 μv/day; 20 μv/week; 50 μv/3 months referred to the input at 25°C.                                                      |                                                        |                                                                                                                                                                                               |
| <b>Temperature Coefficient of Voltage Offset:</b> | 2 μv/°C (referred to input).                                                                                                         |                                                        |                                                                                                                                                                                               |

## TYPICAL PERFORMANCE (with 50,000 ohms input and feedback resistors)

|                            |                                                                                                |                                                 |                                                                |
|----------------------------|------------------------------------------------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|
| <b>Frequency Response:</b> | Flat within 0.01 db (0.1%) dc to 8 kc; within 0.1 db (1%) dc to 40 kc; within 3 db dc to 1 mc. | <b>Output Drift:</b>                            | 35 μv/day; 50 μv/week; 200 μv/3 months (0.002% of full scale). |
|                            |                                                                                                | <b>Temperature Coefficient of Output Drift:</b> | 6 μv/°C.                                                       |

Other ASTRODATA amplifiers include:

### TDA-874 Wide-Band Single Ended Amplifier for amplification after low level commutation.

BANDWIDTH  
dc — 150 kc  
GAINS AVAILABLE FROM  
1 — 5000  
NOISE REFERRED  
TO INPUT  
5 mv rms  
INPUT RESISTANCE  
Greater than  
100 megohms



### TDA-874G Galvanometer Driver Amplifier for raising low level sources to galvanometer levels.

Built-in Galvanometer  
Overload Protection  
ADJUSTABLE DAMPING  
RESISTOR  
0 — 1000 ohms  
GAIN RANGE  
0.5 — 5000  
INPUT RESISTANCE  
Greater than  
100 megohms



### TDA-880 Differential Amplifier for single channel or high-level multiplexing systems.

BANDWIDTH  
dc to 200 cps  
LOW NOISE  
1 μv rms  
Built-in Filtering  
Available to Restrict  
Bandwidth for  
Commuted Data  
Systems.



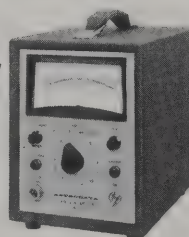
### TOA-110 Chopper Stabilized Operational Amplifier. Versatile modular amplifier for analog control systems.



BANDWIDTH dc — 250 kc  
Long Term Stability, Constant  
Gain-Bandwidth  
VOLTAGE OFFSET ADJUSTABLE TO ZERO  
±1 mv nom. range  
CURRENT OFFSET ADJUSTABLE TO ZERO  
±0.001 μa nom. range

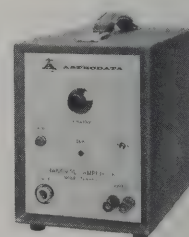
### TDA-121 Nanovoltmeter provides 0.1 μv full scale bridge balance detector for standards and calibration work in the field as well as laboratories.

FULL SCALE RANGES  
±0.1 μv to ±100 mv  
INPUT RESISTANCE  
ALL RANGES  
1 megohm  
Built-in Overload  
Indicator.



### TDA-120 Ultrasensitive Amplifier gives you high gain/low noise amplification for seismic transducer signals, cryogenic studies, strain gage signals.

Gains From 1000 to  
100,000 (optional to  
3,000,000).  
BANDWIDTH  
dc — 100 cps  
NOISE  
0.05 μv rms  
referred to input  
INPUT RESISTANCE  
1 megohm



**ASTRODATA INC.**

240 East Palms Road, Anaheim, California



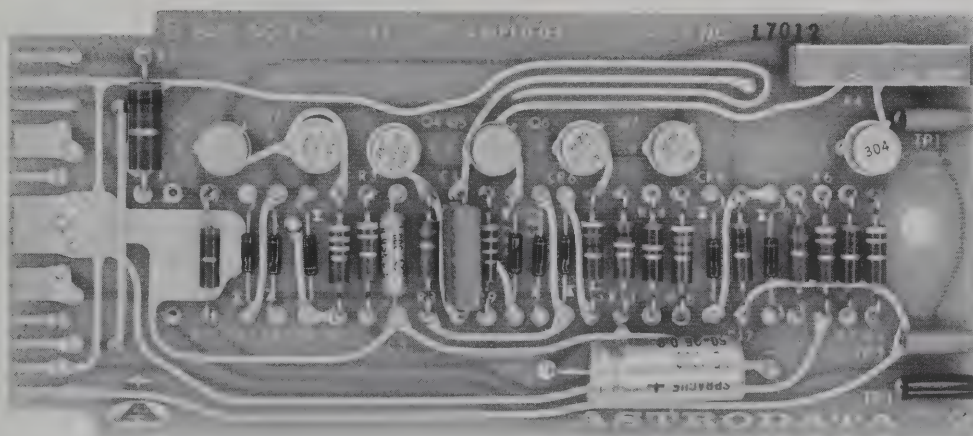
**ASTRODATA**



# MODEL 140 TRANSISTORIZED POTENTIOMETRIC DC AMPLIFIER

**bulletin**

620711



## DESCRIPTION

The ASTRODATA Model 140 DC Amplifier is a fully transistorized unit intended to serve as a line-driver. In a typical application it couples high impedance single-ended sources of voltage into cables which drive distant recording equipment such as oscillographs, analog-to-digital converters, etc. It provides a voltage gain of unity, to signals which range from 0 to  $\pm 5$  volts dc, and will withstand input signals as large as  $\pm 28$  volts dc without damage to the amplifier.

The Model 140 is constructed on an etched circuit board approximately 2.8 inches wide by 6.5 inches long by 0.5 inches thick. It is housed normally in the ASTRODATA Model RM-140 Rack Mounting Unit which accepts up to 24 amplifiers and provides all dc power requirements as well as convenient quick-disconnect facilities for the input-output wiring.

Connections to the amplifier are made through contacts which are an integral part of the circuit board. All contacts are provided with 100% redundancy for reliability. That is, each contact appears on both sides of the board, connected electrically through the board. All contacts are plated with low-stress rhodium over compressively-stressed nickel to achieve maximum environmental protection and long-life low-contact

resistance. The mating connector (Kennedy Industries Type KI 1500-15) has two spring contacts which contact the board on opposite sides, and the contacts are joined together within the connector to provide 100% redundancy of connections.

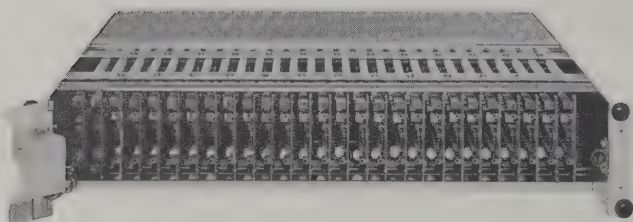
The components of the amplifier circuit are connected to eyelets on the board for maximum ease of repair without damage to the etched wiring. Smaller components such as resistors and diodes have strain-relief loops to further improve reliability. All transistors are fitted with ASTRODATA's exclusive nylon pads which protect the transistor during the soldering operation while still allowing visual and electrical inspection of the transistor leads as they pass through the circuit board.

The amplifier will operate within specifications over an ambient temperature range of  $+20^{\circ}\text{C}$  to  $+50^{\circ}\text{C}$ . Excellent gain stability, linearity and low drift are achieved to provide highest accuracy. The high input resistance and low output resistance, coupled with its ability to operate with a wide range of source impedances, makes the Model TPA-140 an ideal choice for a line-driver amplifier in a wide variety of applications.

# SPECIFICATIONS

## MODEL 140 DC AMPLIFIER

|                                                                             |                                                                                                                                          |                                                                       |                                                                                                                                   |
|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------|
| <b>Input Voltage Range:</b>                                                 | 0 to $\pm 5$ volts dc                                                                                                                    | <b>Zeroing Range:</b>                                                 | At least 100 millivolts, adjustable from front of card                                                                            |
| <b>Maximum Input Voltage:</b>                                               | $\pm 28$ volts dc will not damage unit                                                                                                   | <b>Frequency Response:</b>                                            | dc to 100 kc                                                                                                                      |
| <b>Voltage Gain:</b>                                                        | $1.0 \pm 0.01\%$ at $25^{\circ}\text{C}$                                                                                                 | <b>Load Capability:</b>                                               | $\pm 5$ volts dc or peak ac at 1 milliamp, dc to 200 cps                                                                          |
| <b>Temperature Coefficient of Gain:</b>                                     | Better than $\pm 0.01\% / ^{\circ}\text{C}$                                                                                              | <b>Temperature Range (for operation within these specifications):</b> | $+ 20^{\circ}\text{C}$ to $+ 50^{\circ}\text{C}$                                                                                  |
| <b>Linearity:</b>                                                           | Within $\pm 10$ millivolts from 0 to $\pm 1$ volt dc; within $\pm 1\%$ of output from $\pm 1$ volt to $\pm 5$ volts dc                   | <b>Short Circuit Protection:</b>                                      | Amplifier will not be harmed by an output short circuit under the worst combination of line voltage, input signal and temperature |
| <b>Input Resistance:</b>                                                    | Greater than 1 megohm                                                                                                                    | <b>Power Source:</b>                                                  | $+ 12$ volts and $- 12$ volts at approximately 10 milliamps (provided by Model RM-140 Rack Mounting Unit)                         |
| <b>Output Resistance:</b>                                                   | Less than 15 ohms                                                                                                                        | <b>Size:</b>                                                          | Printed circuit board approximately 2.8 inches wide by 6.5 inches long by 0.5 inches thick                                        |
| <b>Source Resistance Range (for operation within these specifications):</b> | 0 to 10,000 ohms                                                                                                                         | <b>Governing Specifications:</b>                                      | MIL-P-55110, MIL-P-21193(NORD) and MIL-STD-275A(SHIPS)                                                                            |
| <b>Offset Drift:</b>                                                        | After ten minutes warm-up, less than $\pm 10$ millivolts in 72 hours at constant ambient temperature and with constant source resistance |                                                                       |                                                                                                                                   |
| <b>Temperature Coefficient of Offset:</b>                                   | Less than 1 millivolt/ $^{\circ}\text{C}$                                                                                                |                                                                       |                                                                                                                                   |



Model RM-140 Rack Mounting Unit with Model 140 Amplifiers



**ASTRODATA INC.**

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Litho in U. S. A.



**ASTRODATA**



# MODEL RM-140 RACK MOUNTING UNIT AND POWER SUPPLY

**bulletin**

620712



## DESCRIPTION

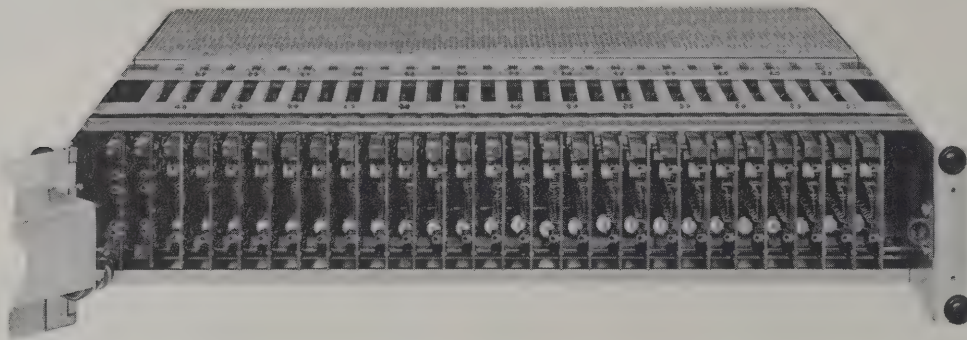
The ASTRODATA Model RM-140 Rack Mounting Unit and Power Supply is intended as an enclosure for one or more Model 140 DC Amplifiers. Up to 24 amplifiers can be accommodated, mounted on  $\frac{5}{8}$ -inch centers across the front of the Rack Mounting Unit. Space is also provided for the power supply regulator card, a spare regulator card, and a spare Model 140 Amplifier card. All necessary dc power to the amplifiers is supplied.

Each amplifier card is guided at the top and bot-

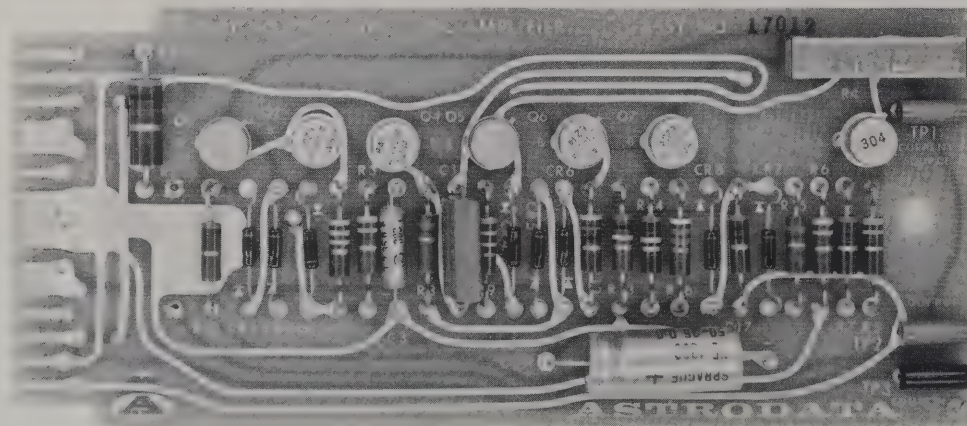
tom by slots in a nylon card guide to ensure smooth and easy insertion and removal. Receptacles for each amplifier connector (Kennedy Industries Type KI 1500-15) provide 100% redundancy of contacts to ensure reliable connections. The front of the unit has a door hinged at the left side and held closed by a quarter-turn captive thumb-screw. Mounted on the door is a power switch, a fuse and a pilot lamp. The unit is louvered at the top and bottom to provide for vertical air flow.

# SPECIFICATIONS

|                               |                                                                            |                      |                                                                                      |
|-------------------------------|----------------------------------------------------------------------------|----------------------|--------------------------------------------------------------------------------------|
| <b>Capacity:</b>              | Up to 24 Model 140 Amplifiers                                              | <b>Connectors:</b>   | Input/Output: Four MS-3102R-28-21P<br>ac Power: One MS-3102R-18-11P                  |
| <b>Power Supply Voltages:</b> | +12 volts and -12 volts at 0 to 500 milliamps                              | <b>Size:</b>         | 19 inches wide by 3½ inches high (panel dimensions) by approximately 16½ inches deep |
| <b>Voltage Tolerance:</b>     | ±5% from no load to full load and from 105 volts to 125 volts line voltage | <b>Panel Finish:</b> | MIL-STD 595, color 26492 (Gray)                                                      |
| <b>Ripple:</b>                | Less than 50 millivolts peak-to-peak                                       | <b>Metal Parts:</b>  | Cadmium plate per QQ-P-416, Type II, Class 2                                         |
| <b>Output Impedance:</b>      | Less than 1 ohm dc to 1 kc                                                 |                      |                                                                                      |
| <b>Power Requirements:</b>    | 105-125 volts ac, 55-65 cps, single phase, approximately 30 watts          |                      |                                                                                      |



Model RM-140 Rack Mounting Unit with Model 140 Amplifiers



MODEL 140 DC AMPLIFIER



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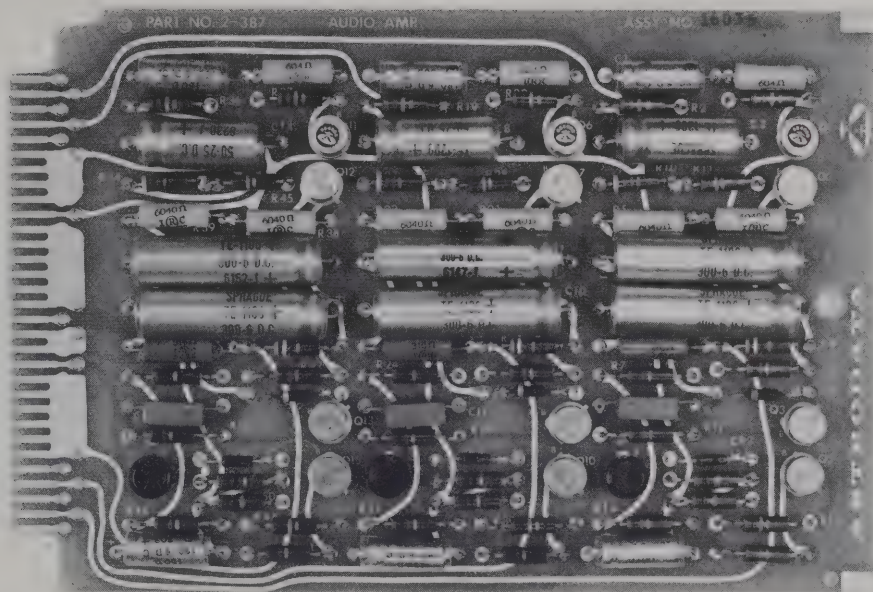
**ASTRODATA**



**MODEL 108  
HIGH PERFORMANCE  
3-CHANNEL  
AUDIO AMPLIFIER**

**bulletin**

621201



**DESCRIPTION**

ASTRODATA's new Model 108 makes available to the audio industry an outstanding new development in a solid-state, modular amplifier for studio use.

Three identical amplifiers, each with a gain of 40 db, are constructed on a single plug-in circuit card. The amplifiers may be used with external attenuators, variable effects equalizers and mixers to perform the functions of preamplifier, booster amplifier, channel amplifier, coupling amplifier, program mixing amplifier or line amplifier. The extremely low noise of the Model 108, coupled with its low distortion at output levels to +18 dbm makes it especially attractive for use in all applications from the microphone input to the line output, where a level of +8 dbm allows a 10 db peak reserve. In any of these applications the amplifiers may be mixed or switched to produce pure monophonic or multi-channel stereophonic program channels.

Of particular significance is the fact that each amplifier is direct coupled, with capacitive coupling used only at the input and output terminals. When several amplifiers are used in tandem, coupling transformers need be used only at the input and output of the system, thereby greatly reducing system cost and minimizing problems caused by magnetically-induced hum. Leakage currents at the amplifier input and output are negligible so that no problems from key clicks result from switching circuits placed

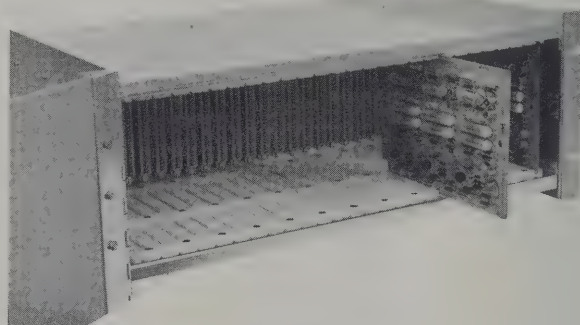
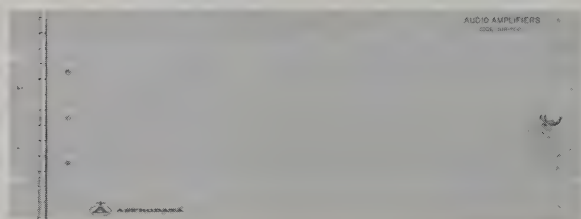
between the amplifiers. Eliminating the coupling transformers also improves the transient response of the over-all system.

Very low noise is assured by a process of input transistor selection. The transistors are pre-aged for 500 hours, during which their noise is measured at selected intervals. Any transistors showing a tendency to generate noise greater than specifications are rejected, and the acceptable transistors are then marked with the ASTRODATA label.

The Model 108 contains three amplifiers on a glass-epoxy circuit board with plated wiring. All components are soldered to eyelets on the board using a flow-soldering technique. Smaller components, such as resistors and diodes, have strain relief loops in their leads, and all transistors are mounted on nylon pads. The circuit board measures 7-7/16-inches long by 4-15/16-inches wide by 1/2-inch thick (including components). Up to 26 cards can be mounted in the ASTRODATA Model 108-200 Rack Mounting Unit. Nylon card guides assure easy insertion and removal of the cards, as well as accurate alignment with the mating connector. Forced air cooling is provided by a muffin fan which draws air in past the cards on one-half of the rack mount and exhausts it from the other half. Connections to signal and dc power wiring are made by taper pins inserted into the mating connectors.

# SPECIFICATIONS

|                                          |                                                            |                                           |                                                                                                                                                              |
|------------------------------------------|------------------------------------------------------------|-------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Gain (each channel)                      | 40 db                                                      | Intermodulation Distortion (SMPTE Method) | Less than 1% at +18 dbm output, 20 cps to 20 kc                                                                                                              |
| Input Impedance                          | 600 ohms                                                   | Inverse Feedback                          | 57 db                                                                                                                                                        |
| Output Impedance                         | Less than 1 ohm                                            | Power Requirements                        | $\pm 18$ volts dc at 25 ma per card at +18 dbm output                                                                                                        |
| Frequency Response at +18 dbm output     | $\pm 0.5$ db 20 cps to 20 kc, 3 db down at 7 cps and 70 kc | Mating Connector                          | Kennedy Industries KI-1500-31                                                                                                                                |
| Maximum Undistorted Output               | +18 dbm                                                    | Size                                      | 4 $\frac{7}{16}$ -in. wide by 7 $\frac{15}{16}$ -in. long by $\frac{1}{2}$ -in. thick                                                                        |
| Equivalent Input Noise (600 ohms source) | -122 dbm, 20 cps to 20 kc                                  | Model 108-200 Rack Mounting Unit          | Holds 26 Model 108 Amplifiers on $\frac{5}{8}$ -in. centers, has hinged front door. Measures 7-in. high x 19-in. wide by 12-in. deep, including cooling fan. |
| Harmonic Distortion                      | Less than 0.25% at +18 dbm output                          |                                           |                                                                                                                                                              |



Model 108-200 Rack Mounting Unit



**ASTRODATA INC.**

240 East Palais Road, Anaheim, California



**ASTRODATA**



# MODELS 113, 114, 115 AND 116 MODULAR AMPLIFIERS

**bulletin**

621006



## DESCRIPTION

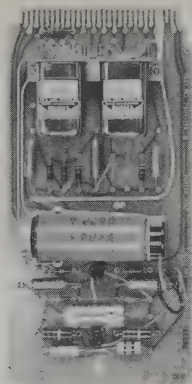
The ASTRODATA Models 113, 114, 115 and 116 comprise a new series of modular amplifiers for use in data systems, analog-to-digital converters, analog computers, and other measuring instruments. Constructed on plug-in etched circuit cards, the new amplifiers extend the scope of applications covered by ASTRODATA's standard Model 110 and 112 solid-state operational amplifiers.

The new amplifiers all have very high (potentiometric-type) input impedance and all are chopper-stabilized. The models 113 and 114 use solid-state choppers, while the Models 115 and 116 use mechanical choppers. The Models 113 and 114 also incorporate a dc-to-dc power supply isolator so that amplifier

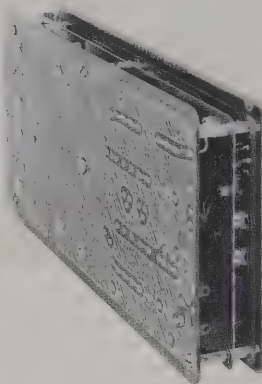
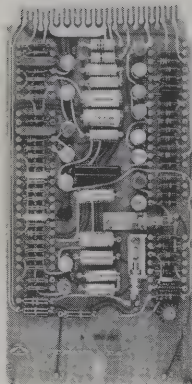
input and output grounds are electrically isolated from the power supply ground. In multi-channel installations each amplifier's ground circuit is therefore isolated from all other amplifier ground circuits, and truly floating.

The Models 113 and 114 are unity gain amplifiers having a bandwidth from dc to 1 megacycle (3 db point). The Model 115 has a bandwidth from dc to 150 kc, and the gain is adjustable over a range from 1 to 200 by means of external customer-supplied resistors which can be placed on a range switch if desired. The Model 116 is a narrow-band, fixed-gain amplifier which can also be supplied with other bandwidths and other gains. Write the manufacturer for details.

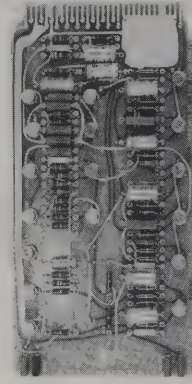
# SPECIFICATIONS



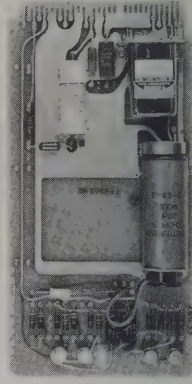
MODEL 115



MODEL 113, 114



MODEL 116



| SPECS              | MODEL 113             | MODEL 114             | MODEL 115             | MODEL 116             |
|--------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Bandwidth          | dc to 1 mc            | dc to 1mc             | dc to 150 kc          | dc to 5.33 cps        |
| Gain               | Unity $\pm 0.01\%$    | Unity $\pm 0.01\%$    | Adj. 1 to 200         | 555.5 $\pm 0.06\%$    |
| Input Impedance    | 100 meg +10 pf        | 100 meg +10 pf        | 100 meg +700 pf       | 20 meg +700 pf        |
| Output Impedance   | <1 ohm                | <1 ohm                | <1 ohm                | <1 ohm                |
| Output             | $\pm 10V @ \pm 10$ ma | $\pm 15V @ \pm 10$ ma | $\pm 10V @ \pm 20$ ma | $\pm 10V @ \pm 10$ ma |
| Settling Time      | 10 $\mu$ sec to 0.01% | 10 $\mu$ sec to 0.01% | 25 $\mu$ sec to 1%    |                       |
| Noise              | <250 $\mu$ v rms      | <250 $\mu$ v rms      | <5 $\mu$ v rms RTI    | <0.4 $\mu$ v rms RTI  |
| Drift              | <15 $\mu$ v/day       | <15 $\mu$ v/day       | <2 $\mu$ v/wk RTI     | <2 $\mu$ v/wk RTI     |
| Power Requirements | +18V @ 150 ma*        | +18V @ 200 ma*        | $\pm 18V @ 100$ ma    | $\pm 18V @ 50$ ma     |

\*Signal input and output grounds are isolated from the power ground circuit by a dc-to-dc power isolator in the Models 113 and 114 amplifiers.

## SIZE:

Models 113 and 114: Power Supply isolator and amplifier card assembly measures  $4\frac{1}{2}$ -inches high by  $1\frac{3}{8}$ -inches wide by 9-inches long. Occupies three "card slots" on  $\frac{5}{8}$ -inch centers. Mates with single Kennedy Industries KI-1500-31 (or equal) connector.

Models 115 and 116: Separate cards for chopper assembly and for amplifier assembly. Chopper assembly measures  $4\frac{1}{2}$ -inches high by  $1\frac{3}{8}$ -inches wide by 9-inches long, occupies two "card slots" on  $\frac{5}{8}$ -inch centers. Amplifier assembly measures  $4\frac{1}{2}$ -inches high by  $\frac{5}{8}$ -inch wide by 9-inches long, occupies one "card slot." Each card mates with a Kennedy Industries KI-1500-31 (or equal) connector.



**ASTRODATA INC.**

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**ASTRODATA**



# MODEL 120 NANOVOLT AMPLIFIER

**bulletin**

630501



## DESCRIPTION

The ASTRODATA Model 120 is a completely transistorized Ultra-Sensitive dc Amplifier, designed to amplify the low-level, low-frequency output signals from geophysical and other type transducers. Fixed gains of from 200 to 1,000,000 are selected by means of a front panel switch. The low noise level of 0.05 microvolts peak-to-peak (referred to the input) assures faithful amplification of input signals as low as 100 nanovolts.

Battery operation assures truly floating amplification,

free from the effects of 60-cycle hum interference. A built-in battery charger permits recharging the batteries when the amplifier is not in use. The amplifier may also be operated directly from the ac power line. Fully charged batteries will allow continuous operation for 20 hours before recharging is necessary, and battery condition may be monitored with the front-panel meter.

The amplifier is constructed in a convenient, lightweight portable cabinet equipped with a carrying handle. Total weight is only 14 pounds.

## TYPICAL APPLICATIONS

Seismographic Signals

Bolometer Signals

Cryogenic Studies

Cell Studies

Bridge Balance Amplifier

Ultra Low-level Strain Gauges

Ultra Low-level Thermocouples

Hall-Effect Studies

## SPECIFICATIONS

|                                        |                                                                                                                                                                                                                                                                                                    |                                 |                                                                                                                       |
|----------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| <b>Type:</b>                           | Floating, shielded.                                                                                                                                                                                                                                                                                | <b>Maximum Output Voltage:</b>  | $\pm 5$ volts peak, 0 to 20 cps.                                                                                      |
| <b>Gain:</b>                           | Fixed steps of 200, 500, 1000, 2000, 5000, 10,000, 20,000, 50,000, 100,000, 200,000, 500,000, 1,000,000.                                                                                                                                                                                           | <b>Maximum Output Current:</b>  | $\pm 5$ ma peak, 0 to 20 cps.                                                                                         |
| <b>Input Resistance:</b>               | At least 1 megohm on all ranges.                                                                                                                                                                                                                                                                   | <b>Minimum Load Resistance:</b> | 1,000 ohms.                                                                                                           |
| <b>Frequency Response:</b>             | dc to 100 cps ( $-3$ db point).                                                                                                                                                                                                                                                                    | <b>Output Resistance:</b>       | Less than 1 ohm.                                                                                                      |
| <b>Gain Accuracy:</b>                  | $\pm 1\%$ (dc).                                                                                                                                                                                                                                                                                    | <b>Power Supply:</b>            | Self-contained batteries and battery charger. Battery condition may be monitored with the front-panel meter.          |
| <b>Gain Stability:</b>                 | $\pm 0.01\%$ /day; $\pm 0.1\%$ /6 months.                                                                                                                                                                                                                                                          | <b>Accessories Furnished:</b>   | Input connector, low thermal input leads, low thermal solder, one complete set of batteries.                          |
| <b>Linearity:</b>                      | $\pm 0.02\%$ (dc).                                                                                                                                                                                                                                                                                 | <b>Output Connectors:</b>       | 5-Way binding posts, $\frac{3}{4}$ -in. spacing.                                                                      |
| <b>Noise Referred to Input:*</b>       | 0.05 $\mu$ V peak-to-peak from 1 cpm to 1 cps;<br>0.25 $\mu$ V peak-to-peak from 1 cpm to 20 cps (99% confidence).                                                                                                                                                                                 | <b>Size:</b>                    | Portable cabinet, approximately 6 $\frac{3}{4}$ -in. wide by 8 $\frac{3}{4}$ -in. high by 10 $\frac{1}{2}$ -in. deep. |
| <b>Offset Drift Referred to Input:</b> | Less than $\pm 0.05$ $\mu$ V dc/hour,<br>0.15 $\mu$ V dc/day, 1 $\mu$ V dc/6 months.                                                                                                                                                                                                               | <b>Weight:</b>                  | Approximately 14 pounds.                                                                                              |
| <b>Zero Control:</b>                   | Provides a 10-turn, continuously adjustable, control and a switch to select zeroing ranges of $\pm 0.5$ , $\pm 5$ , $\pm 50$ , $\pm 500$ and $\pm 5000$ microvolts for correcting the offset of input signals. Stability of zero control is $\pm 0.03\%$ of the range selected by the zero switch. | <b>Colors:</b>                  | Front Panel light green (FED-STD-595, Color 24300).<br>Cabinet dark green (FED-STD-595, Color 34058).                 |
|                                        |                                                                                                                                                                                                                                                                                                    | <b>Cooling:</b>                 | None required; total dissipation approximately 2 watts.                                                               |

\*Noise figures shown are for source resistance of 100 ohms or less. At 2000 ohms source resistance noise is twice that listed above.

**Model 874G Galvanometer Driver Amplifier** for raising low level sources to galvanometer levels.



Built-in Galvanometer  
Overload Protection  
ADJUSTABLE DAMPING  
RESISTOR  
0 — 1000 ohms  
GAIN RANGE  
0.5 — 5000  
INPUT RESISTANCE  
Greater than  
100 megohms

**Model 874 Wide-Band Single Ended Amplifier** for amplification after low level commutation.



BANDWIDTH  
dc — 150 kc  
GAINS AVAILABLE FROM  
1 — 5000  
NOISE REFERRED  
TO INPUT  
5 mv rms  
INPUT RESISTANCE  
Greater than  
100 megohms

**Model 880 Differential Amplifier** for single channel or high-level multi-plexing systems.



BANDWIDTH  
dc to 200 cps  
LOW NOISE  
1  $\mu$ V rms  
Built-in Filtering  
Available to Restrict  
Bandwidth for  
Commuted Data  
Systems.



**ASTRODATA INC.**

240 EAST PALAIS ROAD • ANAHEIM, CALIFORNIA • PHONE: (213) 772-1000



**ASTRODATA**



# MODEL TPA-141 INSTRUMENTATION TAPE RECORDER AMPLIFIER

**bulletin**

621005



## DESCRIPTION

The new Model TPA-141 is a modular, wideband, adjustable-gain amplifier which finds wide use in coupling medium-level signal sources to tape recorders, FM sub-carrier oscillators, strip chart recorders and other instrumentation. The Model TPA-141 provides amplification between 1 and 100 to signals which range in frequency from dc to 200 kc. Eleven gain steps may be selected by means of a front-panel switch. The Model TPA-141 is completely transistorized.

The amplifier circuitry is mounted on an etched-wiring circuit card which is integrated with a front panel assembly. The Model RM-88A Rack Mounting Unit includes a Kennedy Industries Type KI-

1500-31 printed circuit card connector with which the amplifier's connector mates. The Rack Mounting Unit measures only 5¼-inches high by 19-inches wide by 8⅞-inches deep, and will contain up to eight amplifiers.

DC power of plus and minus 20 volts can be supplied from system power supplies or from the ASTRODATA Model 8100-102 Power Supply. The latter can power up to 50 amplifiers in an installation. Wiring for distributing dc power in the Rack Mounting Unit is installed at the factory, and cables for connecting to a power distribution block on the Model 8100-102 Power Supply are furnished with the Rack Mounting Unit.

# SPECIFICATIONS

**Gain Steps:** Fixed steps 1, 1.5, 3, 5, 7, 10, 15, 30, 50, 70 and 100

**Gain Accuracy:**  $\pm 1\%$  at dc

**Gain Stability:**  $\pm 0.1\%$  for 3 months

**Frequency Response:** dc to 200 kc (3 db point)

**Input Resistance:** Greater than 100,000 ohms

**Output Voltage:**  $\pm 10$  volts dc or peak ac, 7 volts rms to 50,000 cps, 4 volts rms to 100,000 cps

**Output Loading:** 50,000 ohms in parallel with 2000 mmf

**Output Resistance:** Less than 50 ohms

**Linearity:**  $\pm 0.1\%$  dc to 1 kc

**Noise:** Less than 45 microvolts peak-to-peak referred to the input plus 0.5 millivolts peak-to-peak referred to the output from 0.05 cps to 100,000 cps

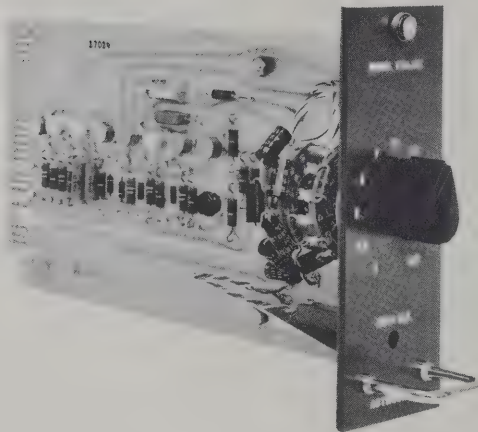
**Size:**  $2\frac{1}{8}$ -inches wide by  $5\frac{1}{4}$ -inches high by  $7\frac{1}{16}$ -inches deep

**Power Requirements:** +20 v and -20 v, supplied by Model 8100-102 Power Supply

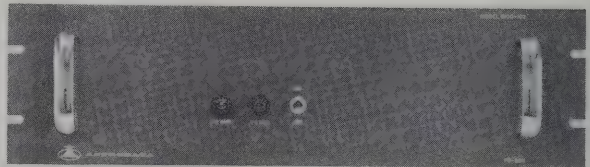
**Rack Mounting Module:** Model RM-88A Module holds up to 8 amplifiers in standard relay rack cabinet. Includes mating connectors for amplifiers and dc power wiring. Size:  $5\frac{1}{4}$ -inches high by 19-inches wide by  $8\frac{3}{8}$ -inches deep behind panel

**Model 8100-102 Power Supply:** Furnishes  $\pm 20$  volts dc power for up to 50 Model TPA-141 Amplifiers. Front panel has power switch, pilot lamp and fuse; rear panel has barrier strip for dc power distribution. Measures  $5\frac{1}{4}$ -inches high by 19-inches wide by 9-inches deep, for rack mounting.

**Finishes:** Panel background Federal STD 595, color 34058 (dark green; semi-gloss)  
Panel lettering silk screen, Federal STD 595, color 37875 (white)



Model TPA-141 Amplifier



Model 8100-102 Power Supply



**ASTRODATA INC.**

240 East Palais Road, Anaheim, California



**ASTRODATA**



# MODEL 121 SOLID-STATE NANOVOLTMETER

**bulletin**

630502



## Features:

- FULL-SCALE RANGES FROM  $\pm 0.1$  MICROVOLT TO  $\pm 100$  MILLIVOLTS
- BUILT-IN FILTER REJECTS SUPERIMPOSED AC SIGNALS
- BUILT-IN OVERLOAD INDICATOR
- 1-MEGOHM INPUT RESISTANCE ON ALL RANGES
- SOLID-STATE CIRCUIT
- WITHSTANDS 1 VOLT INPUT OVERLOAD ON ANY RANGE
- ACCURACY  $\pm 3\%$
- OPTIONAL WIDE-RANGE ZERO SUPPRESSION
- TOLERATES WIDE RANGE OF SOURCE RESISTANCES
- FLOATING CIRCUIT ASSURES HUM-FREE PERFORMANCE
- CONNECTIONS TO EXTERNAL RECORDER
- SELF-CONTAINED BATTERIES AND AC POWER PACK

# Applications:

- MEASURE MINUTE DC POTENTIALS
- SENSITIVE NULL BALANCE INDICATOR
- LOW-LEVEL THERMOCOUPLE MEASUREMENTS
- SENSITIVE VOLTAGE COMPARATOR
- CRYOGENIC STUDIES
- HALL-EFFECT STUDIES
- INFRA-RED CELL STUDIES
- ELECTRO-CHEMICAL CELL STUDIES
- BOLOMETER INDICATOR

## GENERAL DESCRIPTION

The ASTRODATA Model 121 Nanovoltmeter offers an important new concept in instruments to measure ultra-low-level dc voltages. The Model 121 is the first all-transistor unit to provide such high sensitivity, combined with low drift and noise. It is a completely portable unit suitable for laboratory, production line or field testing.

Among the exclusive features which contribute to its accuracy and easy, fool-proof operation is the ability to withstand both dc and ac input overloads of several hundreds- or even thousands-of-times full scale value. Overloads of up to 1 volt dc or ac may be applied to the unit on any range without damage to the instrument.

In addition, filtering is provided so that ac signals (typically 60-cps) superimposed on the dc voltage to be measured are attenuated by a factor of at least 5000 to 1 (74 db) at the meter. This greatly reduces measurement errors arising from this common condition. At the recorder terminals the 60-cps attenuation is at least 120 to 1 (41.6 db) except on the three lowest gain ranges.

In most applications the ASTRODATA Nanovoltmeter will provide accurate measurements even on its most sensitive range, whether operated from the ac power line or from its internal batteries. However, when it is important to use a completely floating meter, battery operation can be employed.

Even when the most careful attention is paid to the manner in which ground connections are made, flow of current from measuring circuit ground to power ground is inevitable. For example, if the potential difference between measuring circuit ground and ac power ground is one volt, and the leakage impedance from circuit to power ground is 10 megohms at 60 cps, a current of  $10^{-7}$  amperes will flow from measuring circuit to power ground. If the source being measured has an internal resistance of 1000 ohms, for example, an interfering ac voltage of 100 microvolts will be superimposed on the dc voltage to be

measured. The ASTRODATA Nanovoltmeter solves this problem by offering battery operation so that **practically infinite isolation from power ground can be achieved.** By breaking the ground loop, interference from ground currents is virtually eliminated. Another important feature of the Model 121 Nanovoltmeter is its built-in overload indicator lamp. Whenever superimposed ac signals become large enough (even after filtering) to drive the amplifier to saturation, this condition is usually not apparent by observation of the meter. However, the overload indicator lamp will light automatically, thus cautioning that the meter may not be reading correctly.

Recorder terminals are provided on the rear of the instrument for connection to external recording or digitizing equipment. Although the unit can deliver an undistorted output of  $\pm 5$  volts on any range, the output voltage is 3.0 volts when the meter indicates full-scale on all ranges down to the 1 microvolt range. For the 0.3 and 0.1 microvolt ranges the output voltage is 1.0 and 0.3 volts, respectively, when the meter is at full-scale. When long tests are to be recorded with the instrument operated from its internal batteries, the battery voltages may be visually checked by turning the METER switch to "+ BATT" and "- BATT" without interrupting the recording or introducing transients into the record.

These features, combined with the ASTRODATA Nanovoltmeter's very high sensitivity, low noise and low drift, provide performance previously unobtainable in instruments for ultra-low voltage measurements. The high input resistance of at least one megohm on all ranges assures negligible loading of the source to be measured. Improved response time and reduced noise when the source resistance is varied over a wide range add a new dimension to the art of measuring minute voltages. Easy portability and the rugged solid-state circuitry extend its range of applications from laboratory to production line and into field measurements.





# SPECIFICATIONS

|                                |                                                                                                                                                                                                                                                                                                                                                                                                                  |
|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Voltage Ranges:</b>         | Full scale center-zero ranges of $\pm 0.1$ micro volt to $\pm 100.0$ millivolts dc in X1, X3, X10, etc., steps.                                                                                                                                                                                                                                                                                                  |
| <b>Input Overload Range:</b>   | Withstands up to 1 volt input on all ranges.                                                                                                                                                                                                                                                                                                                                                                     |
| <b>Input Resistance:</b>       | At least 1 megohm on all ranges.                                                                                                                                                                                                                                                                                                                                                                                 |
| <b>Accuracy:</b>               | $\pm 3\%$ of full-scale on all ranges.                                                                                                                                                                                                                                                                                                                                                                           |
| <b>Zeroing Range:</b>          | Nominally $\pm 3$ microvolts. See Modification Z for optional zero suppression feature.                                                                                                                                                                                                                                                                                                                          |
| <b>Zero Drift:</b>             | Less than $0.05 \mu\text{V}/\text{hour}$ ; $0.15 \mu\text{V}/\text{day}$ ; $1 \mu\text{V}/6$ months (non-cumulative) with shorted input. On $100 \mu\text{V}$ range and higher, drift is less than $0.03\%$ of full-scale per day.                                                                                                                                                                               |
| <b>Noise:</b>                  | Less than $0.005 \mu\text{V}$ rms when source resistance is $100$ ohms or less; less than $0.01 \mu\text{V}$ rms when source resistance is $2000$ ohms or less. With higher source resistances the rms noise is less than $0.01 \left( \frac{R}{2000} \right) \mu\text{V}$ , where R is the source resistance in ohms. On $100 \mu\text{V}$ range and higher, noise and hum is less than $0.02\%$ of full-scale. |
| <b>Step Function Response:</b> | Meter response to step function input (10% to 90% of full-scale) is less than 1 second for source resistance less than $0.5$ megohms.                                                                                                                                                                                                                                                                            |
| <b>60-cps Filtering:</b>       | Built-in filtering allows the following amounts of 60-cps signal to be superimposed on the dc signal to be measured without impairing accuracy. The filtering factor at frequencies other than 60-cps is inversely proportional to frequency.                                                                                                                                                                    |

| NANOVOLTMETER<br>FULL SCALE<br>RANGE | NOMINAL<br>SUPERIMPOSED<br>60-CPS VOLTAGE<br>PEAK-TO-PEAK | FILTERING<br>FACTOR*<br>AT 60 CPS |
|--------------------------------------|-----------------------------------------------------------|-----------------------------------|
| $0.1 \mu\text{V}$                    | $100 \mu\text{V}$                                         | 1000                              |
| $0.3 \mu\text{V}$                    | $200 \mu\text{V}$                                         | 667                               |
| $1 \mu\text{V}$                      | $300 \mu\text{V}$                                         | 300                               |
| $3 \mu\text{V}$                      | $900 \mu\text{V}$                                         | 300                               |
| $10 \mu\text{V}$                     | $1 \text{ mV}$                                            | 100                               |
| $30 \mu\text{V}$                     | $1 \text{ mV}$                                            | 33                                |
| $100 \mu\text{V}$                    | $3.3 \text{ mV}$                                          | 33                                |
| $300 \mu\text{V}$                    | $10 \text{ mV}$                                           | 33                                |
| $1 \text{ mV}$                       | $33 \text{ mV}$                                           | 33                                |
| $3 \text{ mV}$                       | $100 \text{ mV}$                                          | 33                                |
| $10 \text{ mV}$                      | $100 \text{ mV}$                                          | 10                                |
| $30 \text{ mV}$                      | $100 \text{ mV}$                                          | 3.3                               |
| $100 \text{ mV}$                     | $100 \text{ mV}$                                          | 1                                 |

\*The filtering factor is the ratio of the peak-to-peak ac voltage which will not impair accuracy, divided by the full scale range.

**Overload Indicator:** Panel lamp lights automatically when ac-input overloads amplifier thus warning of possible measurement errors.

**Amplifier Gain Range:** Amplifier gain may be selected from 30 to 3 million in steps of X1, X3, X10, etc.

**Amplifier Gain Accuracy:**  $\pm 1\%$

**Amplifier Gain Stability:**  $\pm 0.02\%$  for 1000 hours.

**Amplifier Bandwidth:** Down 3db at 0.2 cps.

**Recorder Output:** Amplifier supplies up to  $\pm 5$  volts at  $\pm 5$  milliamperes at two five-way binding posts on rear panel. Amplifier output connections and front panel meter may be used simultaneously.

**Ground Isolation:** Entire circuit is floating from panel and cabinet by at least 1000 megohms resistance and not more than  $0.01 \text{ mf}$  capacitance. Input may be floated up to  $\pm 300$  volts dc with respect to panel or cabinet. Circuit ground may be connected to cabinet ground at binding post adjacent to output terminals with link provided.

**Power Requirements:** 115 volts rms  $\pm 10\%$ , 50 to 70 cps, approximately 2 watts, or internal batteries. Unit may be operated for approximately 20 hours without ac power between rechargings from self-contained charger.

**Battery Test:** Front panel switch connects meter to volt-meter circuit or to internal batteries for testing. Use of amplifier output terminals is not interrupted during battery tests.

**Battery Types:** Six each Sonotone Type S-102 and six each Sonotone Type S-104. One complete set is furnished with instrument.

**Size:** Portable Model 121:  $8\frac{3}{4}$ -in. high by  $6\frac{3}{4}$ -in. wide by  $10\frac{1}{2}$ -in. deep.

Rack Model 121R:  $8\frac{3}{4}$ -in. high by 19-in. wide by  $10\frac{1}{2}$ -in. deep for relay rack mounting.

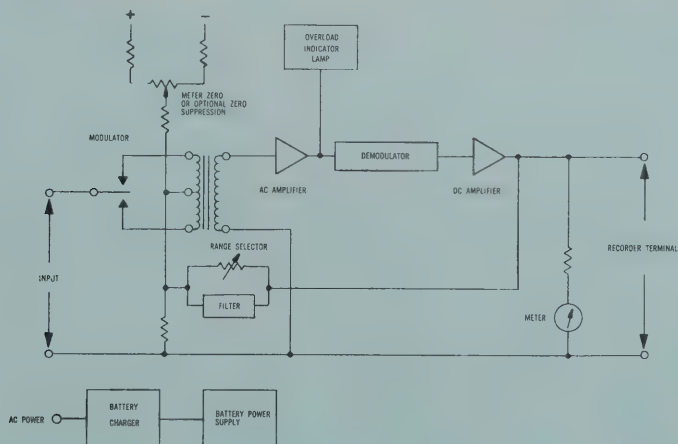
**Weight:** Approximately 15 pounds.

**Accessories Furnished:** Input connector, low thermal input leads, low thermal solder, flux, one complete set of batteries.

## MODIFICATIONS

**Modification R:** Nanovoltmeter is mounted on  $8\frac{3}{4}$ -in. high by 19-in. wide panel for relay rack mounting. Standard notch spacing is provided. The unit extends  $10\frac{1}{2}$ -in. behind the panel.

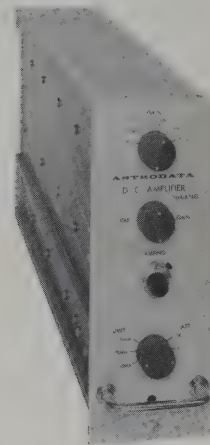
**Modification Z:** Provides wide range of zero suppression for measuring small incremental changes of larger dc voltages. Rotary switch selected steps with concentric vernier control are provided covering ranges of  $\pm 0.5$ ,  $\pm 5$ ,  $\pm 50$ ,  $\pm 500$  and  $\pm 5000$  microvolts. Operation of the zero suppression circuit is independent of the meter range selected. Stability of the zero suppression circuit is  $\pm 0.03\%$  of the full scale suppression range for 24 hours, temperature coefficient  $\pm 0.03\%/^{\circ}\text{F}$ .



SIMPLIFIED BLOCK DIAGRAM OF ASTRODATA NANOVOLTMETER

Other ASTRODATA amplifiers include:

Model TDA-874G — a low-level potentiometric amplifier intended for driving all popularly used galvanometers. The high input impedance, high input-to-ground isolation, wide bandwidth, fast settling time, low noise, low drift and excellent linearity common to other ASTRODATA amplifiers have been retained. Gain range is continuously adjustable from 0.5 to 5000, providing at least  $\pm 2$  inch deflection for most galvanometers. A built-in, continuously adjustable and calibrated damping resistor covers the range from 0 to 1000 ohms. A built-in current limiter assures protection against galvanometer burnout. The input circuit will withstand sustained 10-volt overloads and the output is short-circuit-proof. Full specifications contained in Bulletin 611003.



The ASTRODATA Model 880 is a low noise differential amplifier for use with thermocouples, strain gauges, resistance bridges, and other low-level transducers. Gain Steps of 50, 100, 200, 500 and 1000 are selected by front panel switch. Noise is less than  $1\mu\text{v}$  rms, drift less than  $2\mu\text{v}$  referred to input. Bandwidth is dc to 100 cps. Common mode rejection is 140 db at dc, 120 db at 60 cps; common mode voltage may be as great as  $\pm 300$  volts dc or peak ac. Gain accuracy is  $\pm 0.1\%$ , gain stability is  $\pm 0.02\%$  and dc linearity is  $\pm 0.02\%$ ; provides  $\pm 5$  volts output at  $\pm 10$  ma. Size  $5\frac{1}{4}$ -in. high by  $2\frac{1}{8}$ -in. wide. Eight amplifiers plug into standard 19-inch rack mount requiring only  $5\frac{1}{4}$  inches of vertical panel space. Full specifications contained in bulletin #620601.

The ASTRODATA Model 120 is a shielded, floating amplifier for nanovolt signals. Similar in function and appearance to the Model 121 Nanovoltmeter, the Model 120 provides gain selection from 200 to 1 million in 12 steps. Gain accuracy is  $\pm 1\%$ , gain stability  $\pm 0.02\%$  and dc linearity is  $\pm 0.02\%$ . Bandwidth is dc to 100 cps, and input resistance is constant at 1 megohm on all ranges. Noise is less than  $0.25\mu\text{v}$  peak-to-peak, drift less than  $\pm 0.05\mu\text{v}/\text{hour}$ . Full specifications contained in bulletin #630501.



**ASTRODATA INC.**  
240 EAST PALAIS ROAD • ANAHEIM, CALIFORNIA • PHONE: (213) 772-1000



**ASTRODATA**

# MODEL 122 NANOVOLT INTEGRATOR

**bulletin**

**630801**



## DESCRIPTION

The ASTRODATA Model 122 is a completely transistorized ultra-sensitive dc amplifier, designed to integrate the low-level, low-frequency output signals from geophysical and other type transducers. A bandwidth from dc to 100kc, an open loop gain of approximately 50 million, and a drift of only 0.05  $\mu\text{V}$  per hour at the summing junction provide highest integration accuracy. The low noise level of 0.05 microvolts peak-to-peak (referred to the input) assures faithful integration of input signals as low as 100 nanovolts.

Battery-power assures truly floating operation, free from the effects of 60-cycle hum interference. A built-in battery charger permits recharging the bat-

teries when the unit is not in use. The Model 122 may also be operated directly from the ac power line. Fully charged batteries will allow continuous operation for 20 hours before recharging is necessary, and battery condition may be monitored with the front-panel meter.

The signal to be integrated is applied from the integrator resistor to the front panel connector. Front-panel binding posts allow the user to install an integrator capacitor of his choice and to apply appropriate initial conditioning.

The integrator is constructed in a convenient, lightweight portable cabinet equipped with a carrying handle. Total weight is only 14 pounds.

## TYPICAL APPLICATIONS

Seismographic Signals

Bolometer Signals

Cryogenic Studies

Cell Studies

B-H Loop Core Measurements

Ultra Low-Level Strain Gauges

Ultra Low-Level Thermocouples

Hall-Effect Studies

# SPECIFICATIONS

**Type:** Floating, shielded.  
**Gain:** Approximately  $50 \times 10^6$  open loop.  
**Input Resistance (open loop):** At least 1 megohm.  
**Frequency Response:** dc to 100 kc.  
**Noise Referred to Summing Point:\***  $0.05 \mu\text{V}$  peak-to-peak from 1 cpm to 1 cps;  
 $0.25 \mu\text{V}$  peak-to-peak from 1 cpm to 20 cps (99% confidence).  
**Offset Drift Referred to Summing Point:** Less than  $\pm 0.05 \mu\text{V}$  dc/hour,  $0.15 \mu\text{V}$  dc/day,  $1 \mu\text{V}$  dc/6 months.  
**Zero Control:** Provides a 10-turn, continuously adjustable control, and a switch to select zeroing ranges of  $\pm 0.5$ ,  $\pm 5$ ,  $\pm 50$ ,  $\pm 500$  and  $\pm 5000$  microvolts for correcting the offset of input signals. Stability of zero control is  $\pm 0.03\%$  of the range selected by the zero switch.  
**Maximum Output Voltage:**  $\pm 5$  v peak. (Also displayed on front-panel meter.)  
**Maximum Output Current:**  $\pm 5$  ma peak.

**Minimum Load Resistance:** 1000 ohms.  
**Output Resistance:** Less than 1 ohm.  
**Power Supply:** Self-contained batteries and battery charger. Battery condition may be monitored with the front-panel meter.  
**Accessories Furnished:** Input connector, low thermal input leads, low thermal solder, one complete set of batteries.  
**Output Connectors:** 5-Way binding posts,  $\frac{3}{4}$ -in. spacing.  
**Size:** Portable cabinet, approximately  $6\frac{3}{4}$ -in. wide by  $8\frac{3}{4}$ -in. high by  $10\frac{1}{2}$ -in. deep. Approximately 14 pounds.  
**Weight:**  
**Colors:** Front Panel: Light green (FED-STD-595, Color 24300).  
Cabinet: Dark green (FED-STD-595, Color 34058).  
**Cooling:** None required; total dissipation approximately 2 watts.

\*Noise figures shown are for source resistance of 100 ohms or less. At 2000 ohms, source resistance noise is twice that listed above.

**Model 121 Nanovoltmeter** for measuring minute dc voltages.

FULL SCALE RANGES FROM  $0.1 \mu\text{V}$  to 100 mv  
 WITHSTANDS 1 v on any range  
 REJECTS UP TO 1000 times full scale superimposed 60 cps  
 DC AMPLIFIER GAIN FROM 30 to 1 million  
 Battery or line operated.



**Model 120 Nanovolt Amplifier** for amplification of thermocouple, seismograph and other low-level signals.

GAIN FROM 200 to 1 million  
 BANDWIDTH dc to 100 cps  
 DRIFT  $0.05 \mu\text{V}$  per hour  
 NOISE  $0.05 \mu\text{V}$  peak-to-peak  
 Battery or line operated.



**Model 880 Differential Amplifier** for single channel or high-level multiplexing systems.

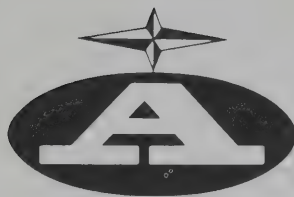
BANDWIDTH dc to 200 cps  
 LOW NOISE  $1 \mu\text{V}$  rms  
 Built-in Filtering Available to Restrict Bandwidth for Commutated Data Systems.



**ASTRODATA INC.**

P.O. Box 3003 • 240 E. Palais Road, Anaheim, California • (714) 772-1000





SERIES 3000

# Analog-to-Digital Converters



- CONVERSION SPEEDS TO 20,000 PER SECOND
- ACCURACY TO 0.01%
- MODULAR, PLUG-IN CONSTRUCTION

Series 3000 high speed Analog-to-Digital Converters are designed to fulfill the requirements of virtually all data acquisition systems. From a library of 13 basic circuit cards, up to 1088 standard, production-line models can be assembled.



**ASTRODATA INC.**

## General Description

Here is a whole family (1088 STANDARD, Production-line models!) of new, high-speed Analog-to-Digital Converters designed to fit the requirements of *virtually all* data acquisition systems. Especially suited for use with time-multiplexed input data, Series 3000 ADC's offer high speed, ultimate accuracy, reliability, and modular, plug-in construction in one compact package.

*ASTRODATA certifies that the entire converter will perform within stated accuracy for at least one year provided a simple zero readjustment and reference voltage check is performed at two-month intervals! These checks are performed from the front of the instrument while mounted in place; no disassembly is required.*

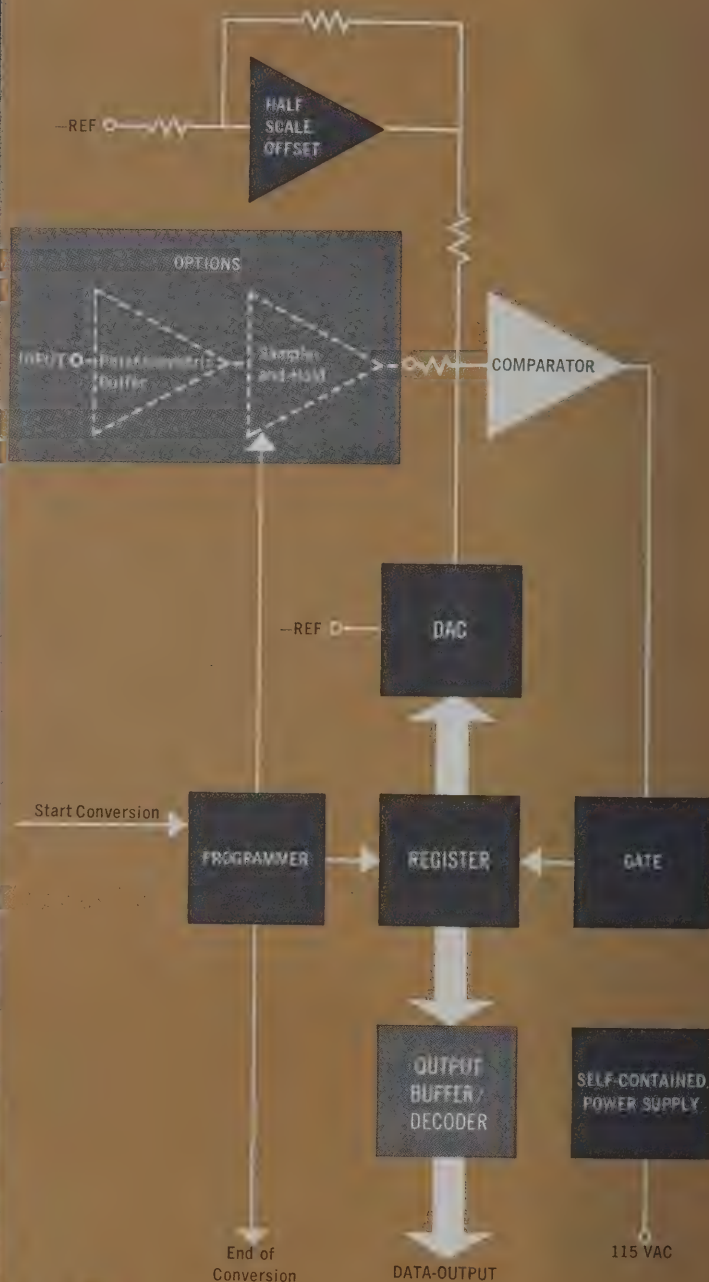
Two basic accuracies and speeds are offered. Where highest speed with medium overall accuracy is desired, decisions are made at the rate of 2.5 microseconds per bit, yielding 20,000 or more conversions per second for 10-bit converters. Where maximum accuracy is required, a basic accuracy of 0.01% is provided with decisions made at the rate of 4 microseconds per bit, yielding approximately 13,500 conversions per second for 14-bit converters.

Each of the output data lines is individually buffered to isolate digital loads from the converter so that transient signals generated in the load will not affect performance. During the conversion process, the buffers are disabled to inhibit data output until the conversion is complete. In addition to eliminating the possibility of false readings, this arrangement gives you another significant advantage:

Standard output logic levels are 0 volts and -6 volts; however, a potentiometer adjustment is provided in the converter which allows the -6 volts level to be changed to any required voltage between -3 and -15 volts. In this way the output logic levels will exactly match the requirements of the data system, eliminating the need for intermediate buffering or level changing.

## SIMPLIFIED BLOCK DIAGRAM

### SERIES 3000 ANALOG-TO-DIGITAL CONVERTER



The comparator uses a radically new chopper-stabilizing technique employing field-effect transistors. Advanced solid-state circuitry has been used throughout Series 3000 ADC's to assure the highest reliability and accuracy.



Integral circuit card connector reduces number of interconnections, enhances reliability.

Integral circuit card connector reduces number of interconnections, enhances reliability.

Integral circuit card connector reduces number of interconnections, enhances reliability.

## MOST SIGNIFICANT DIGITS CONVERTER NETWORK

## Applications:

- MULTIPLEXED DATA
- WIND TUNNEL TESTING
- TELEMETRY
- MEDICAL STUDIES
- SPEECH DIGITIZING
- HIGH-SPEED DATA SYSTEMS
- NUCLEAR SPECTROSCOPY
- MISSILE TEST AND LAUNCH CONTROL
- LABORATORY RESEARCH AND DEVELOPMENT
- COMMAND AND CONTROL SYSTEMS

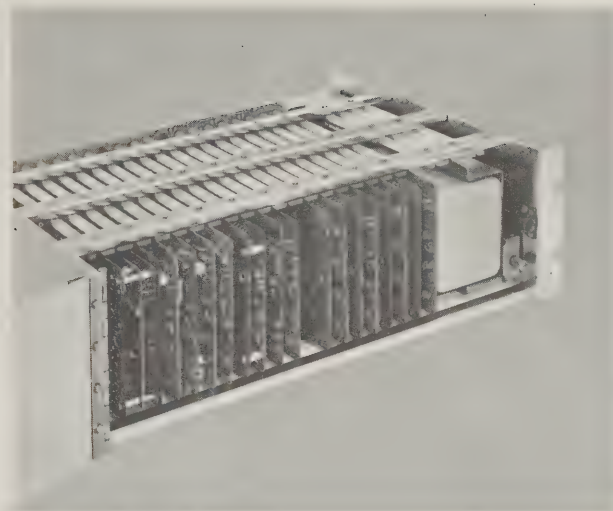
## Variations

No converter, regardless of its speed or accuracy, is useful unless its digital output data is compatible with the data storage or indicating device. To meet the varied requirements of the many digital computers, data recording systems and high-speed printers in use today, ASTRODATA offers a number of standard output format options. These options include absolute value and sign notation, as well as 1's complement and 2's complement notation for negative polarity inputs with binary-type converters. The "minus zero" code is always inhibited so that no ambiguity can exist. With all of these codes, either "positive true" or "negative true" logic may be specified.

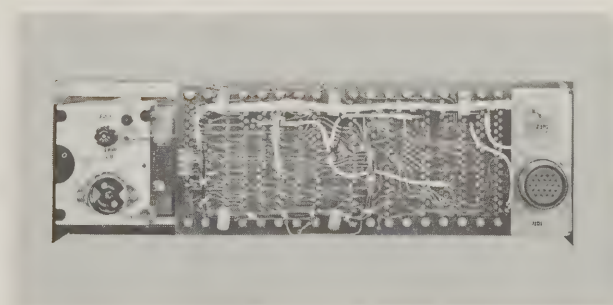
Bipolar operation, with automatic polarity determination of positive and negative input signals, is inherent in all ASTRODATA converters. Resolutions of 3 or 4 decimal digits, as well as 10, 11, 12, 13 or 14 binary digits (and sign) are available. Two voltage ranges, low or high input resistance, and sample and hold input amplifiers can also be incorporated with standard options.

## Construction

All solid-state circuitry is used throughout Series 3000 ADC's. All components are mounted on plug-in, etched-wiring circuit cards. The power supply is also a plug-in unit. The sturdy card frame measures only 5 $\frac{1}{4}$  inches high by 12 $\frac{3}{4}$  inches deep and mounts in a standard relay rack. Nylon card guides assure smooth, easy removal and insertion of cards.



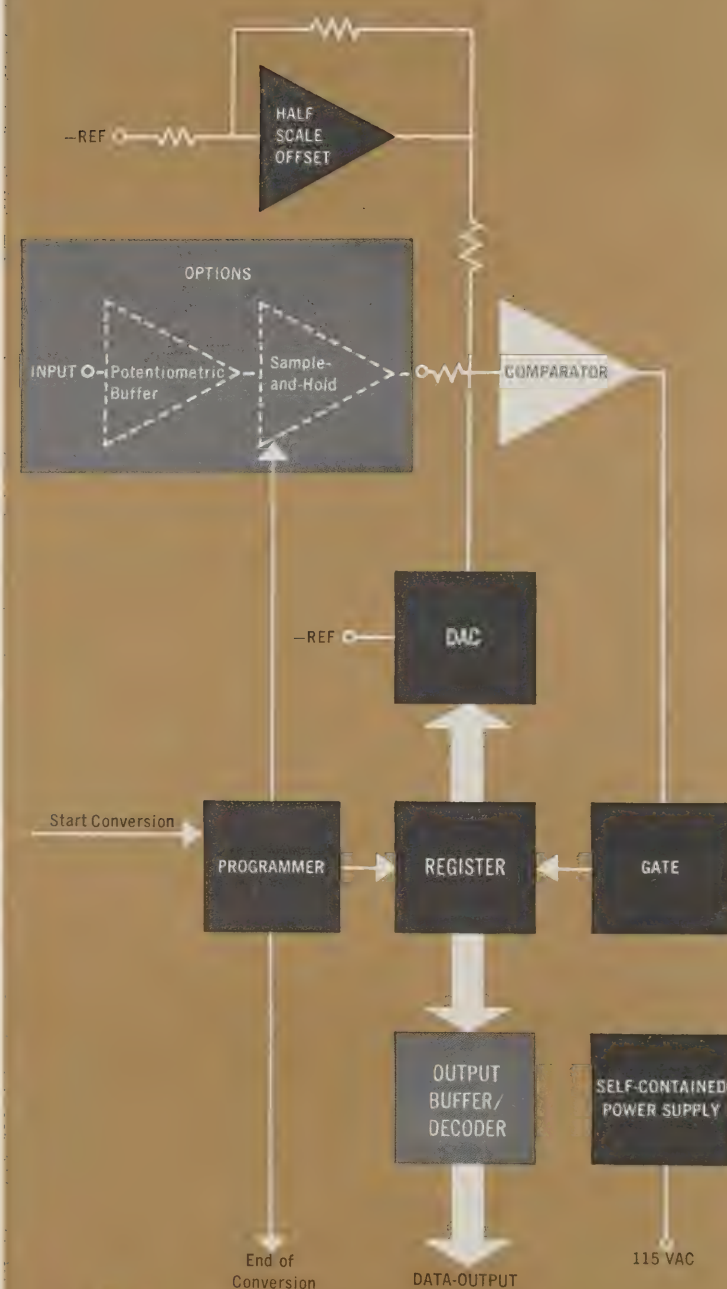
*All installation and operational checks can be performed from the front of the unit. Built-in test points on the front edge of the circuit cards permit the monitoring of every important point in the circuits. Lamps on all flip-flops permit visual inspection of converter operation and indicate the value of the coded data word through the front panel.*



*A "mother board" at the rear of the unit provides neat, etched-circuit wiring between the various circuit cards, eliminating the usual problems of cross-coupling in cables and yielding maximum reliability of performance.*

## SIMPLIFIED BLOCK DIAGRAM

### SERIES 3000 ANALOG-TO-DIGITAL CONVERTER



The comparator uses a radically new chopper-stabilizing technique employing field-effect transistors. Advanced solid-state circuitry has been used throughout Series 3000 ADC's to assure the highest reliability and accuracy.



Specifications

Input Voltage Ranges:

|           |                                                                                                        |
|-----------|--------------------------------------------------------------------------------------------------------|
| Option 1: | ±5.000 (1–10 <sup>N</sup> ) Volts full scale                                                           |
| Option 2: | ±5.12 (1–2 <sup>M</sup> ) Volts full scale                                                             |
| Option 3: | ±10.000 (1–10 <sup>N</sup> ) Volts full scale                                                          |
| Option 4: | ±10.24 (1–2 <sup>M</sup> ) Volts full scale<br>N=number of decimal digits<br>M=number of binary digits |

Input Amplifier Options:

|           |                                                                                                                                        |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------|
| Option 1: | No input amplifier. Input resistance is 2000 ohms on ±10.000 and ±10.24 volt models, 1000 ohms on ±5.000 and ±5.12 volt models.        |
| Option 2: | Potentiometric Buffer Amplifier. Input resistance is 100 megohms paralleled by 10pf for all voltage ranges.                            |
| Option 3: | Sample-and-Hold Amplifier. Input resistance is 4000 ohms on ±10.000 and ±10.24 volt models, 2000 ohms on ±5.000 and ±5.12 volt models. |
| Option 4: | Potentiometric Buffer and Sample-and-Hold Amplifiers. Input resistance is 100 megohms paralleled by 10pf for all voltage ranges.       |

Number of Digits:

|                     |                                               |
|---------------------|-----------------------------------------------|
| Decimal Converters: | 3 or 4 decimal digits, and sign.              |
| Binary Converters:  | 10, 11, 12, 13 or 14 binary digits, and sign. |

|                         |                                                                                     |
|-------------------------|-------------------------------------------------------------------------------------|
| Polarity Determination: | Automatic; polarity indication is provided as an additional bit in the output data. |
|-------------------------|-------------------------------------------------------------------------------------|

|                                                                                                |                                                                                                                                                                                       |
|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Absolute Accuracy* (for one year, with bimonthly checks of zero and scale factor adjustments): | Worst case sum of: noise, linearity (monotonicity),settling time, digitizing rate errors, offset drift and scale factor (gain) drift. Complete error analysis available upon request. |
|------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

| With Input Option          | Overall Accuracy †<br>Option 1 | Overall Accuracy †<br>Option 2 |
|----------------------------|--------------------------------|--------------------------------|
| No Input Amplifier         | ±0.01% F.S. ±½ LSD             | ±0.05% F.S. ±½ LSD             |
| Potentiometric Buffer      | ±0.025% F.S. ±½ LSD            | ±0.065% F.S. ±½ LSD            |
| Sample-and-Hold            | ±0.035% F.S. ±½ LSD            | ±0.08% F.S. ±½ LSD             |
| Buffer and Sample-and-Hold | ±0.05% F.S. ±½ LSD             | ±0.1% F.S. ±½ LSD              |

\*at 25°C, zero ohms source resistance (99.7% confidence).

†When full scale ranges of ±5.000 or ±5.12 volts are selected, above accuracy percentages are increased by ± 0.005% .  
F.S. = Full Scale; LSD = Least Significant Digit.

Temperature Coefficient of Accuracy (at 25°C ± 20°C):

| With Input Option          | With Accuracy Option 1 | With Accuracy Option 2 |
|----------------------------|------------------------|------------------------|
| No Input Amplifier         | 15 ppm/°C              | 30 ppm/°C              |
| Potentiometric Buffer      | 15 ppm/°C              | 30 ppm/°C              |
| Sample-and-Hold            | 20 ppm/°C              | 35 ppm/°C              |
| Buffer and Sample-and-Hold | 20 ppm/°C              | 35 ppm/°C              |

|                  |                                                                                                           |
|------------------|-----------------------------------------------------------------------------------------------------------|
| Digitizing Time: | Includes settling time for multiplexed data and minimum sampling time with Sample-and-Hold input options. |
|------------------|-----------------------------------------------------------------------------------------------------------|

| With Input Option           | With Accuracy Option 1  | With Accuracy Option 2    |
|-----------------------------|-------------------------|---------------------------|
| No Input Amplifier          | 7μsec + 4μsec/decision  | 7μsec + 2.5μsec/decision  |
| Potentiometric Buffer       | 12μsec + 4μsec/decision | 12μsec + 2.5μsec/decision |
| Sample-and-Hold             | 18μsec + 4μsec/decision | 18μsec + 2.5μsec/decision |
| Buffer and Sample-and -Hold | 18μsec + 4μsec/decision | 18μsec + 2.5μsec/decision |

Number of Decisions:

|                     |                                           |
|---------------------|-------------------------------------------|
| Decimal Converters: | 4 for each decimal digit plus 1 for sign. |
| Binary Converters:  | 1 for each binary digit plus 1 for sign.  |

Effects of Signal Source Impedance:

|                 |                                                                                                                                                                                                                                                                                            |
|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Loading Errors: | When the source resistance is other than zero ohms, the additional error due to finite input resistance is $100\left(1-\frac{R_{in}}{R_s+R_{in}}\right)\%$ where R <sub>s</sub> is the source resistance in ohms, and R <sub>in</sub> is the input resistance of the input option in ohms. |
| Noise Errors:   | When input buffer amplifiers are used (input options #2 and #4), an additional error of 0.001% for each 1000 ohms of source resistance must be added to the percentage figures listed in the accuracy table.                                                                               |

|                   |                                                                                                                                                                                                                                                                                                                                         |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Linearity Errors: | When input buffer or sample-and-hold amplifiers are <b>not</b> used (input option No. 1) a current step of 0.5ma is applied to the signal source by the input circuit of the converter. If the source impedance is not purely resistive, the resulting measurement error is equal to the residue remaining after one decision interval. |
|-------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Example:  
A 10-volt full scale converter having a decision interval of 2.5 micro-

seconds is fed from a source equivalent to a 100-ohm resistor shunted by a 0.0078mf capacitor.

The residue, E<sub>R</sub>, is  $IR e^{-\frac{t}{RC}}$

$$\frac{t}{RC} = \frac{2.5 \times 10^{-6}}{100 \times 0.0078 \times 10^{-6}} = 3.2$$
$$E_R = 0.5 \times 10^{-3} \times 100 e^{-3.2} = 0.002 \text{ volts.}$$

As a percentage of full scale,

$$\frac{E_R}{E_{FS}} = \frac{0.002}{10} \times 100\% = 0.02\% \text{ error.}$$

All other effects:

All specifications (other than loading, noise and linearity errors remain unchanged for all source resistances up to 10,000 ohms.

Parallel Digital Outputs:

|                           |                                                                                                                                                                                                                                                   |
|---------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Decimal Converters:       | 4 for each decimal digit (8-4-2-1 code) and 1 for sign.                                                                                                                                                                                           |
| Binary Converters:        | 1 for each binary digit and 1 for sign.                                                                                                                                                                                                           |
| Logic Levels:             | Negative True Logic: $0 \pm \begin{smallmatrix} 0.3 \\ -0.5 \end{smallmatrix}$ volts indicates binary zero and minus $-6 \pm \begin{smallmatrix} 0.6 \\ -0.9 \end{smallmatrix}$ volts indicates binary one and plus.                              |
| Positive True Logic:      | $0 \pm \begin{smallmatrix} 0.3 \\ -0.5 \end{smallmatrix}$ volts indicates binary one and minus $-6 \pm \begin{smallmatrix} 0.6 \\ -0.9 \end{smallmatrix}$ volts indicates binary zero and plus.                                                   |
| Logic Level Adjustment:   | The -6 volts clamp level is adjustable by internal potentiometer to any desired voltage between -3 and -15 volts.. Clamp level is set at factory to $-6 \pm \begin{smallmatrix} 0.6 \\ -0.9 \end{smallmatrix}$ volts unless otherwise instructed. |
| Short Circuit Protection: | Output buffers are not damaged by inadvertent shorts to ground.                                                                                                                                                                                   |
| Maximum Output Current:   | Maximum load current to ground to maintain clamp regulation is $\frac{18-E_c}{3.9}$ ma.,where E <sub>c</sub> is the absolute value of the voltage to which the clamp is set.                                                                      |

Maximum current to a negative voltage when output is at zero volts is 10ma.

|                           |                                                                                              |
|---------------------------|----------------------------------------------------------------------------------------------|
| Digital Codes:            |                                                                                              |
| Decimal Converters:       | Absolute value and sign.                                                                     |
| Binary Converters:        | Absolute value, 1's complement, or 2's complement, and sign. "Minus zero" code is inhibited. |
| End of Conversion Signal: | Output control line is $0 \pm \begin{smallmatrix} 0.3 \\ -0.5 \end{smallmatrix}$ volts       |

External Trigger:

Sample-and-Hold Operation:

during the conversion process, is negative all other times. Output voltages are the same as for the digital code output lines, and the same considerations for voltage range apply.

A negative pulse with minimum amplitude -6 volts, minimum width 2 microseconds and maximum rise time 1 microsecond (into 1000 ohms) resets unit and initiates conversion.

The "end of conversion" signal connects the digital data to the output lines and places the sample-and-hold amplifier in the "follow" mode. The "start conversion" signal may be applied after a minimum delay of 18 microseconds or, if the input signals are commutated, 18 microseconds after the input signal appears. Upon receipt of the "start conversion" signal the converter register resets, the "convert control" line becomes false, and the sample-and-hold circuit switches to "hold" within 2 microseconds. The short-time jitter (or aperture time) of the hold operation is ±0.1μsec. The input signal may be removed or commutated to a new value at any time after the switch to "hold" occurs.

When the sample-and-hold option is selected, the signal polarity indicated by the digital output code value is opposite to the polarity of the input signal.

Front Panel Readout:

Incandescent lamps, one for each bit and sign.

Decimal models display data in 4-2-2-1 code and 9's complement negative notation.

Binary models display negative values as 1's complement or 2's complement.

Conversion to 8-4-2-1 code in decimal models and/or absolute value and sign in both models is accomplished in the output buffer amplifiers.

Maintenance Aids:

A circuit card puller tool is stored on the rear of the hinged front door, and an extender card is stored in an unused card slot if space is available, or is furnished separately.

Front Panel Finish:

Per FED-STD-595. Unless otherwise specified, color number is 26492 (pearl gray) with engraving filled black.

Power Requirements:

115 volts AC ± 10%, 50-65 cps. All power supplies are self-contained.

Size:

5¼" high by 19" wide by 12¾" deep for rack mounting. (Add 3¾" to depth to clear mating connectors.)

## How to order

### CONNECTOR DATA:

Connectors located on rear of converter.

Analog Input:

BNC Type. Ground return is isolated from the chassis.

Digital Output:

Type MS 3102A 24 28S. Mating connector type MS 3106B-24 28P is furnished with converter. Digital ground return is isolated from the chassis.

Pin Connections:

| Pin No. | Function             |                             |
|---------|----------------------|-----------------------------|
| A       | Signal Conversion    |                             |
| B       | Sign                 |                             |
|         | Bit Weights          |                             |
|         | BCD Code             |                             |
|         | Bit Weights          |                             |
|         | Binary Code          |                             |
| 1       | 1 x 10 <sup>1</sup>  | 1                           |
| 2       | 2 x 10 <sup>1</sup>  | 2                           |
| 3       | 3 x 10 <sup>1</sup>  | 3                           |
| 4       | 4 x 10 <sup>1</sup>  | 4                           |
| 5       | 5 x 10 <sup>1</sup>  | 5                           |
| 6       | 6 x 10 <sup>1</sup>  | 6                           |
| 7       | 7 x 10 <sup>1</sup>  | 7                           |
| 8       | 8 x 10 <sup>1</sup>  | 8                           |
| 9       | 9 x 10 <sup>1</sup>  | 9                           |
| 10      | 1 x 10 <sup>2</sup>  | 10                          |
| 11      | 2 x 10 <sup>2</sup>  | 20                          |
| 12      | 3 x 10 <sup>2</sup>  | 30                          |
| 13      | 4 x 10 <sup>2</sup>  | 40                          |
| 14      | 5 x 10 <sup>2</sup>  | 50                          |
| 15      | 6 x 10 <sup>2</sup>  | 60                          |
| 16      | 7 x 10 <sup>2</sup>  | 70                          |
| 17      | 8 x 10 <sup>2</sup>  | 80                          |
| 18      | 9 x 10 <sup>2</sup>  | 90                          |
| 19      | 1 x 10 <sup>3</sup>  | 100                         |
| 20      | 2 x 10 <sup>3</sup>  | 200                         |
| 21      | 3 x 10 <sup>3</sup>  | 300                         |
| 22      | 4 x 10 <sup>3</sup>  | 400                         |
| 23      | 5 x 10 <sup>3</sup>  | 500                         |
| 24      | 6 x 10 <sup>3</sup>  | 600                         |
| 25      | 7 x 10 <sup>3</sup>  | 700                         |
| 26      | 8 x 10 <sup>3</sup>  | 800                         |
| 27      | 9 x 10 <sup>3</sup>  | 900                         |
| 28      | 1 x 10 <sup>4</sup>  | 1000                        |
| 29      | 2 x 10 <sup>4</sup>  | 2000                        |
| 30      | 3 x 10 <sup>4</sup>  | 3000                        |
| 31      | 4 x 10 <sup>4</sup>  | 4000                        |
| 32      | 5 x 10 <sup>4</sup>  | 5000                        |
| 33      | 6 x 10 <sup>4</sup>  | 6000                        |
| 34      | 7 x 10 <sup>4</sup>  | 7000                        |
| 35      | 8 x 10 <sup>4</sup>  | 8000                        |
| 36      | 9 x 10 <sup>4</sup>  | 9000                        |
| 37      | 1 x 10 <sup>5</sup>  | 10000                       |
| 38      | 2 x 10 <sup>5</sup>  | 20000                       |
| 39      | 3 x 10 <sup>5</sup>  | 30000                       |
| 40      | 4 x 10 <sup>5</sup>  | 40000                       |
| 41      | 5 x 10 <sup>5</sup>  | 50000                       |
| 42      | 6 x 10 <sup>5</sup>  | 60000                       |
| 43      | 7 x 10 <sup>5</sup>  | 70000                       |
| 44      | 8 x 10 <sup>5</sup>  | 80000                       |
| 45      | 9 x 10 <sup>5</sup>  | 90000                       |
| 46      | 1 x 10 <sup>6</sup>  | 100000                      |
| 47      | 2 x 10 <sup>6</sup>  | 200000                      |
| 48      | 3 x 10 <sup>6</sup>  | 300000                      |
| 49      | 4 x 10 <sup>6</sup>  | 400000                      |
| 50      | 5 x 10 <sup>6</sup>  | 500000                      |
| 51      | 6 x 10 <sup>6</sup>  | 600000                      |
| 52      | 7 x 10 <sup>6</sup>  | 700000                      |
| 53      | 8 x 10 <sup>6</sup>  | 800000                      |
| 54      | 9 x 10 <sup>6</sup>  | 900000                      |
| 55      | 1 x 10 <sup>7</sup>  | 1000000                     |
| 56      | 2 x 10 <sup>7</sup>  | 2000000                     |
| 57      | 3 x 10 <sup>7</sup>  | 3000000                     |
| 58      | 4 x 10 <sup>7</sup>  | 4000000                     |
| 59      | 5 x 10 <sup>7</sup>  | 5000000                     |
| 60      | 6 x 10 <sup>7</sup>  | 6000000                     |
| 61      | 7 x 10 <sup>7</sup>  | 7000000                     |
| 62      | 8 x 10 <sup>7</sup>  | 8000000                     |
| 63      | 9 x 10 <sup>7</sup>  | 9000000                     |
| 64      | 1 x 10 <sup>8</sup>  | 10000000                    |
| 65      | 2 x 10 <sup>8</sup>  | 20000000                    |
| 66      | 3 x 10 <sup>8</sup>  | 30000000                    |
| 67      | 4 x 10 <sup>8</sup>  | 40000000                    |
| 68      | 5 x 10 <sup>8</sup>  | 50000000                    |
| 69      | 6 x 10 <sup>8</sup>  | 60000000                    |
| 70      | 7 x 10 <sup>8</sup>  | 70000000                    |
| 71      | 8 x 10 <sup>8</sup>  | 80000000                    |
| 72      | 9 x 10 <sup>8</sup>  | 90000000                    |
| 73      | 1 x 10 <sup>9</sup>  | 100000000                   |
| 74      | 2 x 10 <sup>9</sup>  | 200000000                   |
| 75      | 3 x 10 <sup>9</sup>  | 300000000                   |
| 76      | 4 x 10 <sup>9</sup>  | 400000000                   |
| 77      | 5 x 10 <sup>9</sup>  | 500000000                   |
| 78      | 6 x 10 <sup>9</sup>  | 600000000                   |
| 79      | 7 x 10 <sup>9</sup>  | 700000000                   |
| 80      | 8 x 10 <sup>9</sup>  | 800000000                   |
| 81      | 9 x 10 <sup>9</sup>  | 900000000                   |
| 82      | 1 x 10 <sup>10</sup> | 1000000000                  |
| 83      | 2 x 10 <sup>10</sup> | 2000000000                  |
| 84      | 3 x 10 <sup>10</sup> | 3000000000                  |
| 85      | 4 x 10 <sup>10</sup> | 4000000000                  |
| 86      | 5 x 10 <sup>10</sup> | 5000000000                  |
| 87      | 6 x 10 <sup>10</sup> | 6000000000                  |
| 88      | 7 x 10 <sup>10</sup> | 7000000000                  |
| 89      | 8 x 10 <sup>10</sup> | 8000000000                  |
| 90      | 9 x 10 <sup>10</sup> | 9000000000                  |
| 91      | 1 x 10 <sup>11</sup> | 10000000000                 |
| 92      | 2 x 10 <sup>11</sup> | 20000000000                 |
| 93      | 3 x 10 <sup>11</sup> | 30000000000                 |
| 94      | 4 x 10 <sup>11</sup> | 40000000000                 |
| 95      | 5 x 10 <sup>11</sup> | 50000000000                 |
| 96      | 6 x 10 <sup>11</sup> | 60000000000                 |
| 97      | 7 x 10 <sup>11</sup> | 70000000000                 |
| 98      | 8 x 10 <sup>11</sup> | 80000000000                 |
| 99      | 9 x 10 <sup>11</sup> | 90000000000                 |
| 100     | 1 x 10 <sup>12</sup> | 100000000000                |
| 101     | 2 x 10 <sup>12</sup> | 200000000000                |
| 102     | 3 x 10 <sup>12</sup> | 300000000000                |
| 103     | 4 x 10 <sup>12</sup> | 400000000000                |
| 104     | 5 x 10 <sup>12</sup> | 500000000000                |
| 105     | 6 x 10 <sup>12</sup> | 600000000000                |
| 106     | 7 x 10 <sup>12</sup> | 700000000000                |
| 107     | 8 x 10 <sup>12</sup> | 800000000000                |
| 108     | 9 x 10 <sup>12</sup> | 900000000000                |
| 109     | 1 x 10 <sup>13</sup> | 1000000000000               |
| 110     | 2 x 10 <sup>13</sup> | 2000000000000               |
| 111     | 3 x 10 <sup>13</sup> | 3000000000000               |
| 112     | 4 x 10 <sup>13</sup> | 4000000000000               |
| 113     | 5 x 10 <sup>13</sup> | 5000000000000               |
| 114     | 6 x 10 <sup>13</sup> | 6000000000000               |
| 115     | 7 x 10 <sup>13</sup> | 7000000000000               |
| 116     | 8 x 10 <sup>13</sup> | 8000000000000               |
| 117     | 9 x 10 <sup>13</sup> | 9000000000000               |
| 118     | 1 x 10 <sup>14</sup> | 10000000000000              |
| 119     | 2 x 10 <sup>14</sup> | 20000000000000              |
| 120     | 3 x 10 <sup>14</sup> | 30000000000000              |
| 121     | 4 x 10 <sup>14</sup> | 40000000000000              |
| 122     | 5 x 10 <sup>14</sup> | 50000000000000              |
| 123     | 6 x 10 <sup>14</sup> | 60000000000000              |
| 124     | 7 x 10 <sup>14</sup> | 70000000000000              |
| 125     | 8 x 10 <sup>14</sup> | 80000000000000              |
| 126     | 9 x 10 <sup>14</sup> | 90000000000000              |
| 127     | 1 x 10 <sup>15</sup> | 100000000000000             |
| 128     | 2 x 10 <sup>15</sup> | 200000000000000             |
| 129     | 3 x 10 <sup>15</sup> | 300000000000000             |
| 130     | 4 x 10 <sup>15</sup> | 400000000000000             |
| 131     | 5 x 10 <sup>15</sup> | 500000000000000             |
| 132     | 6 x 10 <sup>15</sup> | 600000000000000             |
| 133     | 7 x 10 <sup>15</sup> | 700000000000000             |
| 134     | 8 x 10 <sup>15</sup> | 800000000000000             |
| 135     | 9 x 10 <sup>15</sup> | 900000000000000             |
| 136     | 1 x 10 <sup>16</sup> | 1000000000000000            |
| 137     | 2 x 10 <sup>16</sup> | 2000000000000000            |
| 138     | 3 x 10 <sup>16</sup> | 3000000000000000            |
| 139     | 4 x 10 <sup>16</sup> | 4000000000000000            |
| 140     | 5 x 10 <sup>16</sup> | 5000000000000000            |
| 141     | 6 x 10 <sup>16</sup> | 6000000000000000            |
| 142     | 7 x 10 <sup>16</sup> | 7000000000000000            |
| 143     | 8 x 10 <sup>16</sup> | 8000000000000000            |
| 144     | 9 x 10 <sup>16</sup> | 9000000000000000            |
| 145     | 1 x 10 <sup>17</sup> | 10000000000000000           |
| 146     | 2 x 10 <sup>17</sup> | 20000000000000000           |
| 147     | 3 x 10 <sup>17</sup> | 30000000000000000           |
| 148     | 4 x 10 <sup>17</sup> | 40000000000000000           |
| 149     | 5 x 10 <sup>17</sup> | 50000000000000000           |
| 150     | 6 x 10 <sup>17</sup> | 60000000000000000           |
| 151     | 7 x 10 <sup>17</sup> | 70000000000000000           |
| 152     | 8 x 10 <sup>17</sup> | 80000000000000000           |
| 153     | 9 x 10 <sup>17</sup> | 90000000000000000           |
| 154     | 1 x 10 <sup>18</sup> | 100000000000000000          |
| 155     | 2 x 10 <sup>18</sup> | 200000000000000000          |
| 156     | 3 x 10 <sup>18</sup> | 300000000000000000          |
| 157     | 4 x 10 <sup>18</sup> | 400000000000000000          |
| 158     | 5 x 10 <sup>18</sup> | 500000000000000000          |
| 159     | 6 x 10 <sup>18</sup> | 600000000000000000          |
| 160     | 7 x 10 <sup>18</sup> | 700000000000000000          |
| 161     | 8 x 10 <sup>18</sup> | 800000000000000000          |
| 162     | 9 x 10 <sup>18</sup> | 900000000000000000          |
| 163     | 1 x 10 <sup>19</sup> | 1000000000000000000         |
| 164     | 2 x 10 <sup>19</sup> | 2000000000000000000         |
| 165     | 3 x 10 <sup>19</sup> | 3000000000000000000         |
| 166     | 4 x 10 <sup>19</sup> | 4000000000000000000         |
| 167     | 5 x 10 <sup>19</sup> | 5000000000000000000         |
| 168     | 6 x 10 <sup>19</sup> | 6000000000000000000         |
| 169     | 7 x 10 <sup>19</sup> | 7000000000000000000         |
| 170     | 8 x 10 <sup>19</sup> | 8000000000000000000         |
| 171     | 9 x 10 <sup>19</sup> | 9000000000000000000         |
| 172     | 1 x 10 <sup>20</sup> | 10000000000000000000        |
| 173     | 2 x 10 <sup>20</sup> | 20000000000000000000        |
| 174     | 3 x 10 <sup>20</sup> | 30000000000000000000        |
| 175     | 4 x 10 <sup>20</sup> | 40000000000000000000        |
| 176     | 5 x 10 <sup>20</sup> | 50000000000000000000        |
| 177     | 6 x 10 <sup>20</sup> | 60000000000000000000        |
| 178     | 7 x 10 <sup>20</sup> | 70000000000000000000        |
| 179     | 8 x 10 <sup>20</sup> | 80000000000000000000        |
| 180     | 9 x 10 <sup>20</sup> | 90000000000000000000        |
| 181     | 1 x 10 <sup>21</sup> | 100000000000000000000       |
| 182     | 2 x 10 <sup>21</sup> | 200000000000000000000       |
| 183     | 3 x 10 <sup>21</sup> | 300000000000000000000       |
| 184     | 4 x 10 <sup>21</sup> | 400000000000000000000       |
| 185     | 5 x 10 <sup>21</sup> | 500000000000000000000       |
| 186     | 6 x 10 <sup>21</sup> | 600000000000000000000       |
| 187     | 7 x 10 <sup>21</sup> | 700000000000000000000       |
| 188     | 8 x 10 <sup>21</sup> | 800000000000000000000       |
| 189     | 9 x 10 <sup>21</sup> | 900000000000000000000       |
| 190     | 1 x 10 <sup>22</sup> | 1000000000000000000000      |
| 191     | 2 x 10 <sup>22</sup> | 2000000000000000000000      |
| 192     | 3 x 10 <sup>22</sup> | 3000000000000000000000      |
| 193     | 4 x 10 <sup>22</sup> | 4000000000000000000000      |
| 194     | 5 x 10 <sup>22</sup> | 5000000000000000000000      |
| 195     | 6 x 10 <sup>22</sup> | 6000000000000000000000      |
| 196     | 7 x 10 <sup>22</sup> | 7000000000000000000000      |
| 197     | 8 x 10 <sup>22</sup> | 8000000000000000000000      |
| 198     | 9 x 10 <sup>22</sup> | 9000000000000000000000      |
| 199     | 1 x 10 <sup>23</sup> | 10000000000000000000000     |
| 200     | 2 x 10 <sup>23</sup> | 20000000000000000000000     |
| 201     | 3 x 10 <sup>23</sup> | 30000000000000000000000     |
| 202     | 4 x 10 <sup>23</sup> | 40000000000000000000000     |
| 203     | 5 x 10 <sup>23</sup> | 50000000000000000000000     |
| 204     | 6 x 10 <sup>23</sup> | 60000000000000000000000     |
| 205     | 7 x 10 <sup>23</sup> | 70000000000000000000000     |
| 206     | 8 x 10 <sup>23</sup> | 80000000000000000000000     |
| 207     | 9 x 10 <sup>23</sup> | 90000000000000000000000     |
| 208     | 1 x 10 <sup>24</sup> | 100000000000000000000000    |
| 209     | 2 x 10 <sup>24</sup> | 200000000000000000000000    |
| 210     | 3 x 10 <sup>24</sup> | 300000000000000000000000    |
| 211     | 4 x 10 <sup>24</sup> | 400000000000000000000000    |
| 212     | 5 x 10 <sup>24</sup> | 500000000000000000000000    |
| 213     | 6 x 10 <sup>24</sup> | 600000000000000000000000    |
| 214     | 7 x 10 <sup>24</sup> | 700000000000000000000000    |
| 215     | 8 x 10 <sup>24</sup> | 800000000000000000000000    |
| 216     | 9 x 10 <sup>24</sup> | 900000000000000000000000    |
| 217     | 1 x 10 <sup>25</sup> | 1000000000000000000000000   |
| 218     | 2 x 10 <sup>25</sup> | 2000000000000000000000000   |
| 219     | 3 x 10 <sup>25</sup> | 3000000000000000000000000   |
| 220     | 4 x 10 <sup>25</sup> | 4000000000000000000000000   |
| 221     | 5 x 10 <sup>25</sup> | 5000000000000000000000000   |
| 222     | 6 x 10 <sup>25</sup> | 6000000000000000000000000   |
| 223     | 7 x 10 <sup>25</sup> | 7000000000000000000000000   |
| 224     | 8 x 10 <sup>25</sup> | 8000000000000000000000000   |
| 225     | 9 x 10 <sup>25</sup> | 9000000000000000000000000   |
| 226     | 1 x 10 <sup>26</sup> | 10000000000000000000000000  |
| 227     | 2 x 10 <sup>26</sup> | 20000000000000000000000000  |
| 228     | 3 x 10 <sup>26</sup> | 30000000000000000000000000  |
| 229     | 4 x 10 <sup>26</sup> | 40000000000000000000000000  |
| 230     | 5 x 10 <sup>26</sup> | 50000000000000000000000000  |
| 231     | 6 x 10 <sup>26</sup> | 60000000000000000000000000  |
| 232     | 7 x 10 <sup>26</sup> | 70000000000000000000000000  |
| 233     | 8 x 10 <sup>26</sup> | 80000000000000000000000000  |
| 234     | 9 x 10 <sup>26</sup> | 90000000000000000000000000  |
| 235     | 1 x 10 <sup>27</sup> | 100000000000000000000000000 |
| 236     | 2 x 10 <sup>27</sup> | 200000000000000000000000000 |
| 237     | 3 x 10 <sup>27</sup> | 300000000000000000000000000 |
| 238     | 4 x 10 <sup>27</sup> | 400000000000000000000000000 |
| 239     | 5 x 10 <sup>27</sup> | 500000000000000000000000000 |
| 240     | 6 x 10 <sup>27</sup> | 600000000000000000000000000 |
| 241     | 7 x 10 <sup>27</sup> | 700000000000000000000000000 |
| 242     | 8 x 10 <sup>27</sup> | 8                           |





## DC INSTRUMENTATION AMPLIFIERS: THEIR DESIGN AND USE\*

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bulletin

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We shall discuss here three basic methods of obtaining linear amplification for direct current signals as they are applied to instrumentation amplifiers. Following this we shall discuss some of the circuit arrangements which are used to accomplish certain jobs--their advantages and disadvantages. We will also discuss various types of differential amplifiers, the definition and measurement of common mode voltage rejection and, finally, the use of both differential and single-ended amplifiers with low-level transducers where common-mode contamination presents measurement problems which must be overcome.

Figure 1A shows the simplest form of dc amplifier, two direct-coupled transistors in cascade. Note that there are no reactive elements between the stages or in the input or output circuits. Such an amplifier can be designed to operate well over the band from dc to very high frequencies, but the fluctuations of dc offset, commonly known as drift, is an inherent disadvantage to this circuit. Because it exhibits such poor drift characteristics, it has a very high temperature coefficient of offset, and is very susceptible to power supply voltage fluctuations.

Another form of dc amplifier is the chopper-type shown in Figure 1B. Here the input signal is chopped at a fast rate, amplified by an ac-coupled amplifier (which may be even broadly tuned to the chopper frequency) and finally, demodulated and filtered to retrieve the ampli-

fied input signal. Generally speaking, an electro-mechanical chopper is used because of its low thermal effect. Chopper frequencies are usually between 60 and 600 cps. The main source of error voltages is stray

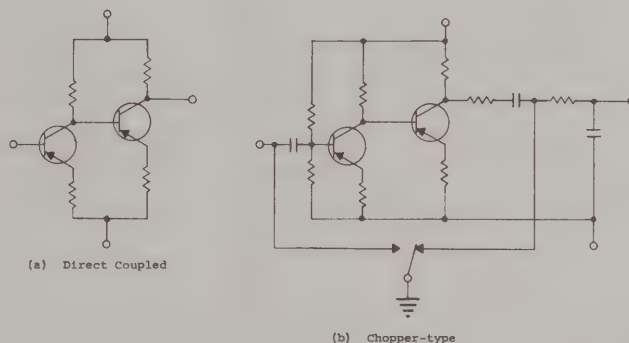


Fig. 1. Direct-Coupled Amplifiers

coupling of the driving ac voltages into the signal circuit. This effect is minimized by careful shielding and by appropriate phasing of the driving voltage. In instrument choppers the relay contacts are usually brought out through the case at the opposite end from the coil terminals, and it also helps to select an excitation frequency different from the ac line frequency or its harmonics.

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It should be noted that such a modulated-carrier type amplifier is phase-sensitive; if the sign of the input dc voltage is reversed, the phase of the ac voltage changes by 180 degrees, and the sign of the dc output voltage will also reverse in the correct manner.

Modulated-carrier type amplifiers permit dc amplification with very substantial gain, without the use of carefully regulated power supplies. The use of synchronous vibrators in the manner shown in Figure 1 permits one, moreover, to obtain dc amplification with very low drift.

Because it is necessary to remove the carrier frequency from the output signal with a filter, the frequency range of this type of amplifier is usually restricted to the band from dc to about 1/10th to 1/5th the carrier frequency. Presently available commercial models of this circuit generally have a bandwidth of from dc to about 100 cps.

A third form of direct-coupled amplifier is the chopper-stabilized amplifier shown in Figure 2. This device consists of a differential dc amplifier shown within the large triangle and a chopper-type amplifier shown at the lower part of the drawing.  $R_1C_1$  and  $R_2C_2$  are low-pass and high-pass filters, respectively.  $R_3C_3$  is a low-pass filter to eliminate the chopper frequency.

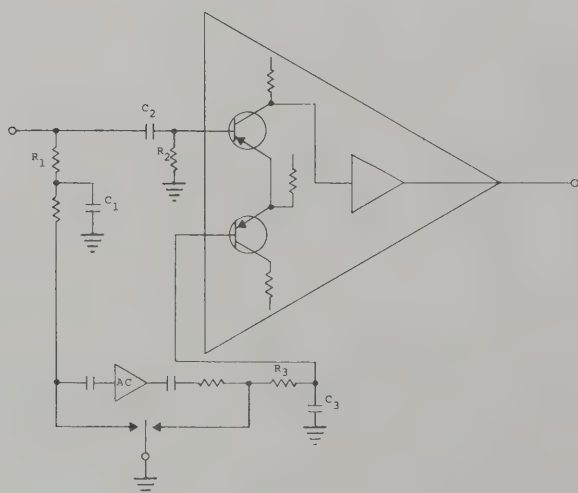


Fig. 2. Chopper-Stabilized DC Amplifier

If we designate the gain of the chopper amplifier as  $A_1$  and the gain of the dc differential amplifier as  $A_2$  it can be seen that the amplification factor for high frequencies is equal to  $A_2$  while the amplification factor for dc and very low frequencies is  $A_1A_2$ .

The modulated-carrier channel precedes the dc amplifier as far as the dc and low frequency components of the signal are concerned. Since this channel is not affected by voltage changes in the power supply, it acts essentially as an input stage having a relatively high gain  $A_1$  and very low drift. Such an arrangement reduces the effect of drift in the dc amplifier channel effectively by a factor equal to the gain  $A_1$  of the modulated-carrier channel. Although it will still pay to keep the drift of the dc amplifier channel to a minimum, the most significant dc error voltages will now be those acting at the input to the modulated-carrier amplifier channel as discussed above.

The chopper-stabilized amplifier circuit is very popular, and is used in practically all quality dc amplifiers. The frequency response can be made very flat from dc to several hundred kc, it has very excellent linearity, low drift and very low output impedance. A typical chopper-stabilized amplifier might have a gain in the dc portion of about five thousand and a gain in the chopper portion of about ten thousand, yielding an amplification factor at dc of about fifty million. In order to keep the bandwidth of the over-all amplifier relatively constant as the gain of the amplifier is changed by the application of feedback, some manufacturers vary the gain of the dc amplifier along with the feedback factor to keep a constant gain-bandwidth product. This technique is called "auto gain" and results in performance of the amplifier which is independent of gain for the parameters of bandwidth, settling time, chopper intermodulation, input resistance and linearity.

So far we have discussed some of the ways in which dc amplification can be accomplished, and I would like to discuss now some of the uses to which these dc amplifiers can be put. I think the best known application of dc amplifiers is that of an operational amplifier in analog computers. As shown in Figure 3, the circuit



consists of a high-gain dc amplifier which has a phase inversion, an input and a feedback resistor. The most important single characteristic of the operational amplifier is the fact that the input current or the current through resistor  $R_1$  is always equal to the feedback current which flows through  $R_2$ . This means that the current flowing out of the summing junction into the amplifier must always be nearly zero. For example, suppose that a net gain of ten is desired in the circuit and an input voltage of 1 volt is impressed across the input terminals and  $R_1$  is made to be 1,000 ohms. This means that an input current of 1 milliampere will flow through  $R_1$ . Since the current through the feedback resistor must also be equal to 1 milliampere and we desire an output current of 10 volts, we must make the value of  $R_2$  equal to 10,000 ohms. Therefore, the gain of the circuit is determined by  $R_2/R_1$ , or, in this case, 10,000/1,000 or 10.

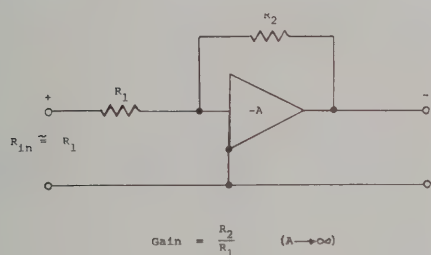


Fig. 3. Operational Amplifier

The junction of the input resistor  $R_1$ , the feedback resistor  $R_2$ , and the input to the amplifier is called the summing junction, since this is the point where the sum of the input current and feedback current must be nearly zero. This means that the voltage drop from the summing junction to ground must also be nearly zero. But it can't be exactly zero because, if it were, then we would have no output from the amplifier. Remembering that this amplifier may have a gain of about 50 million, for a 10-volt output signal, the voltage across the summing junction would be 1/50-millionth of the 10-volt output, or approximately 0.2 microvolts.

For all practical purposes, this is considered zero in relation to the amplifier input signal of 1 volt. Also, since there is a very small voltage drop across the summing junction, there must be some small current flowing into the amplifier. Variations in the summing junction voltage and the current flowing into the amplifier produce second-order errors in the amplification of the over-all circuit. To be sure, these offsets are very small, but their change over a range of operating temperatures and with time tend to degrade the performance of the amplifier.

To correct for the effect of changes in the offset voltage and the offset current, ASTRODATA installs on its operational amplifiers two zero controls. One control reduces the offset voltage to zero and the other one reduces the offset current to zero. Once set up, the values of  $R_1$  and  $R_2$  can be changed over a very wide range without changing the performance of the amplifier except for absolute gain. The typical range of the voltage offset control is  $\pm 1$  millivolt and the voltage offset drift of the amplifier is only about 6 microvolts per hour at the summing junction. The offset current control has a range of  $\pm 1$  millimicroampere and the drift of this current is about 0.06 mua per hour. The net result is that, if the amplifier is set up for a gain of 1, the output drift of the amplifier is only 30 microvolts per hour and the temperature coefficient of output drift is only 10 microvolts per degree C.

The operational amplifier can be used as a summing amplifier by providing additional inputs to the summing junction. In this case, the sum of all the input currents must be equal to the feedback current and the output voltage is thus proportional to the algebraic sum of all the input currents. Also, the resistor  $R_2$  may be replaced by a capacitor and the net result is an integrating amplifier. If we start with a completely discharged capacitor and apply a step function input to the circuit, the output voltage will rise linearly with time. If we suddenly remove the step function, thus reducing the input current to zero, the output voltage will remain constant except for the minor variations of summing junction drift and temperature coefficient which was discussed above.

If we return to the operational amplifier using a resistive feedback element and apply a standard voltage to the input circuit and use a standard resistor for  $R_1$ , the output voltage of the amplifier will be directly proportional to the value of  $R_2$ . This means that the circuit can be used for a direct reading ohmmeter in which the output voltage is directly proportional to the resistance under test. This technique is commonly used in digital ohmmeters where the digital reading must be directly proportional to resistance.

And, finally, if we omit resistor  $R_1$  and consider that the voltage drop across the summing junction is practically zero, then we can insert the circuit in a path in which we want to measure current. In this case the current will flow into the summing junction and thence through the feedback resistor. For example, if we wanted the output voltage to be 10 volts in response to a 1-milliampere input current, the value of  $R_2$  would be 10,000 ohms, since this value is necessary to have 1 milliampere flow from the summing junction to the output at full scale. If we recall the fact that the voltage drop across the summing junction is only about two-tenths of a microvolt, with an input current of 1 milliampere the effective resistance across the summing junction is about two-tenths of a milliohm. Such an arrangement lends itself very neatly to the measurement of current where a very very low shunt resistance is desired.

Let's return now to a differential amplifier similar to that shown in the chopper-stabilized amplifier of Figure 2 and arrange the feedback circuit as shown in Figure 4. If the upper input to the amplifier is driven positively with respect to ground and no inversion occurs in the amplifier so that the output also goes positive, then a positive voltage will be fed back from the voltage divider  $R_1$  and  $R_2$  to the lower input of the differential amplifier. Let's assume that we again want to obtain an amplification of 10 so that one volt in produces 10 volts out. If we make the ratio  $\frac{R_1 + R_2}{R_2}$  at 10 to 1, 1/10th of the output voltage will be returned to the input of the differential amplifier. If the input voltage is 1 volt then the feedback voltage

is also 1 volt and the voltage drop across the differential input to the amplifier will be nearly zero. In this case, recalling that the amplifier might have a gain of 50 million, the differential input to the amplifier would actually be 0.2 microvolts under these conditions. Since the differential input voltage to the amplifier is nearly zero, there can be no current drawn from the input circuit and we have obtained a circuit which has nearly infinite input resistance. In practical circuits we might have an input current of between 1 and 10 millimicroamperes and this current divided by the input voltage of 1 volt yields an input resistance in excess of 100 megohms. This circuit is called a potentiometric amplifier, and it can have all of the desirable properties of the operational amplifier such as low drift, low noise, high gain, wide bandwidth, low output resistance. In addition, it has a practically infinite input resistance. However, the potentiometric amplifier does not lend itself to performing the operational tasks which are desired of the operational amplifier such as integrating, summing, use as a current meter, etc.

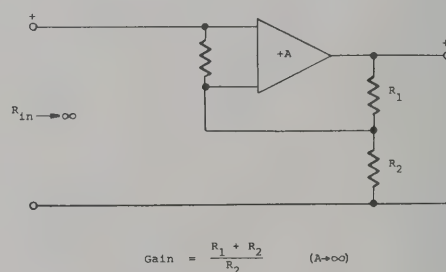


Fig. 4. Potentiometric Amplifier

I would like to point out here that the amplifier obviously cannot have an infinite bandwidth, and therefore, there must be some delay in the output of the amplifier in response to a step function input. This means that when a step function is applied to the amplifier there is a certain time delay before feedback can be applied to the input. During this time a considerable current can be drawn from the source. Since



this current is eventually reduced to nearly zero by virtue of the potentiometric feedback, it can be considered that the input circuit of the amplifier behaves like a capacitor in response to a step function. The size of this equivalent capacitor is directly related to the settling time of the amplifier, which in turn is a function of its bandwidth. So the input impedance of the potentiometric amplifier is neither a real resistance nor a real capacitance, but is a parameter which is a function of the bandwidth and the gain of the amplifier. For this reason, the input impedance of the potentiometric amplifier is usually stated as some large resistance (typically 100 megohms) in shunt with a capacitance (typically 1000  $\mu\text{f}$  for a wide band, high-gain potentiometric amplifier). This is contrasted to the operational amplifier where the input resistance is determined by the value of the resistor between the source and the summing junction.

All of the amplifiers we have discussed thus far are classed as single-ended amplifiers. This means that one of the input terminals is common to one of the output terminals. In contrast to this, a differential amplifier is defined as one which will amplify the voltage which appears between two of its input terminals without regard to whatever voltage appears from either of those input terminals to a third terminal which we normally call ground. A typical bridge-type differential amplifier is shown in Figure 5. The two resistors marked  $R_1$  are made equal and the two resistors  $R_2$  are also made equal, and this configuration forms a Wheatstone bridge. In this circuit, the differential input terminals are isolated from the amplifier's output terminals by the

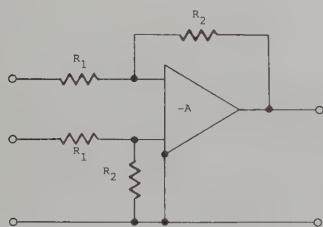


Fig. 5. Bridge-Type Differential Amplifier

resistors  $R_2$ . The differential input is that voltage which is applied between the terminals connected to  $R_1$ , while the common-mode input is the voltage which exists between either of the two differential input terminals and the output ground terminal.

Consider, for a moment, that the two differential input terminals are shorted together and that a common-mode voltage is connected between that junction and the ground terminal. A current caused by the common-mode voltage will flow through the upper resistor  $R_1$  and through  $R_2$  to the output which can be considered at ground when no differential input signal is applied. The common-mode voltage will also cause a current to flow through the lower resistor  $R_1$  and the resistor  $R_2$  to ground. If the resistors marked  $R_1$  and  $R_2$  are equal, then there will be no potential difference existing across the summing junction of the differential amplifier caused by flow of current from the common-mode source. Under these conditions, there would be no output from the amplifier, and we would consider that this amplifier has infinite common-mode rejection. Note that if there is any unbalance in the resistors which form the Wheatstone bridge, a differential potential will develop at the summing junction caused by the common-mode voltage, and this differential voltage will be amplified through the amplifier and appear as an output. Therefore, under those conditions, the differential amplifier will not have perfect common-mode rejection. This condition often arises when an unbalanced source such as a thermocouple is used as the differential input transducer. In addition, the impedances  $R_2$  are generally partly reactive since stray wiring capacities are involved, and the bridge can be balanced generally at only one frequency. In commercial differential amplifiers of this type, the lower resistor  $R_2$  is usually made adjustable to accommodate for resistive source unbalances and an adjustable capacitor is placed across it to balance the bridge at the most commonly encountered common-mode voltage frequency of 60 cps.

It should be fairly obvious that this type of circuit is very sensitive to changes in transducer unbalance and to changes of common-mode voltage frequency. However, this amplifier can be built quite inexpensively.

Several well-known amplifiers use this circuit, including the Electro Instruments Models A-12 and A-15, the Epsco Model DA-102, the Minneapolis-Honeywell Accu-data-3, the Cubic Model 1002A and the CEC Model 1-555. The Redcor Model 361 is a special version of the bridge-type differential amplifier in which the error caused by the common-mode voltage is sensed within the amplifier and this error is electronically servoed to re-balance the bridge automatically.

Typical features of this circuit include excellent linearity, wide frequency response, good gain stability and low output impedance. With the exception of the Redcor, it is also an inexpensive amplifier. However, it is very susceptible to changes of input transducer unbalance and common-mode voltage frequency in achieving good common-mode rejection. Also, it has only moderately low noise and drift, and has low input resistance.

Another method of achieving input-output isolation, hence differential operation, is to use an input isolator such as shown in Figure 6. The Beckman-Fitgo, Neff, Offner and Kin-Tel amplifiers all use variations of this circuit. A potentiometric circuit is shown in which the input voltage is chopped and coupled through a transformer to an amplifier. At the output of the amplifier

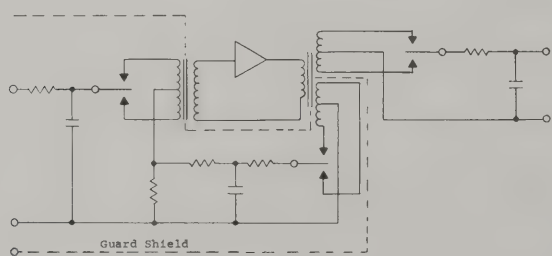


Fig. 6. Amplifier With Input Isolator

a transformer couples the signal to two demodulator circuits. One circuit provides positive feedback to the input of the amplifier to achieve a potentiometric input circuit while the other demodulator delivers the output. Since there is no ohmic connection between the input circuit and output, the leakage resistance is usually very high, in the order of thousands of megohms.

The effective capacitive coupling the input and output circuit is maintained as low as possible through the use of a guard shield which is connected at the transducer to the source of common-mode voltage.

This circuit has three basic disadvantages. They are:

1. The frequency response is limited to a fraction of the chopper frequency which is usually driven at a 400-cps rate.
2. The linearity of the amplifier is dependent on the linearity of the isolators used in the feed-back and output circuits.
3. The output power available from the amplifier is usually very small unless the output isolator is followed by a second amplifier.

However, this circuit does have the advantage of offering excellent common-mode rejection over a wide range of common-mode voltage frequencies and over a wide range of transducer source resistance unbalance.

A third method of achieving input-output isolation involves the use of an output isolator as shown in Figure 7. A potentiometric, chopper-stabilized input amplifier is used which requires the use of a floating guarded power supply. After amplification to the full output level, the isolator chops the waveform and couples it through two transformers to a demodulator where it is filtered and delivered to the load. By operating the isolator at a high level, transistor choppers can be used operating at a very high frequency, typically 35 kc. This improves the frequency response of the overall amplifier to approximately 5-kc at the 3-db point.

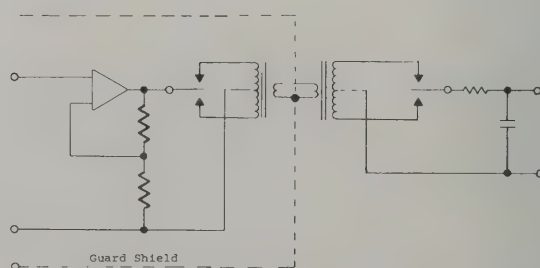


Fig. 7. Amplifier With Output Isolator



At the same time, the potentiometric input circuit is retained to achieve a high input resistance, and excellent common-mode rejection is also achieved. ASTRODATA and Dynamic Instruments both use this circuit. One important advantage of this circuit is that overload protection can be applied to the input amplifier without having to include the isolator in the overload protection feedback circuit. A second advantage is that the output circuit can be floated from both input and chassis or power ground so that the output currents of several amplifiers do not have to return through a common ground path.

An obvious disadvantage is the fact that the linearity and the gain stability of the amplifier are dependent on the characteristics of the dc-to-dc isolator. Also, unless an output amplifier is provided, the power which can be delivered to the load is relatively small.

We have talked a little about common-mode rejection and how it is achieved by several types of amplifiers, but we haven't defined it as yet. If we consider the simple diagram of Figure 8, we recall that in any differential amplifier there is a certain amount of leakage between the differential input terminals and the output terminals. In the bridge amplifier, these impedances are

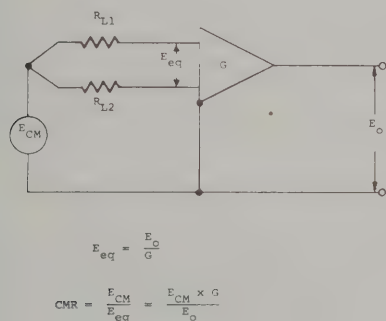


Fig. 8. Definition of Common-Mode Rejection

resistors shunted by capacitors, while in the isolated amplifiers they are the leakage resistance across the isolator and the leakage capacitance which appears between input and output. However, it is not necessary to know anything about the magnitude or character of these leakage impedances to define the common-mode rejection of any given amplifier.

If we remember that these leakage impedances do exist, and we deliberately place an unbalance in the input circuit of the amplifier by making  $R_{L1}$  different from  $R_{L2}$ , and then if we apply a common-mode voltage  $E_{cm}$ , we will obtain a differential input to the amplifier  $E_{eq}$ . This equivalent voltage can be measured by noting the value of the output voltage which is obtained when a known amount of common-mode voltage is present. The value of  $E_{eq}$  is obtained by dividing the output voltage by the gain of the amplifier. Then, the common-mode rejection is defined by the ratio of the common-mode voltage to the voltage which is required as a differential input to produce the same output as caused by the common-mode voltage. In this case, the common-mode rejection ratio is calculated as the common-mode voltage times the gain of the amplifier divided by the output voltage which is obtained in response to the common-mode input. Taking a typical example, suppose that a common-mode voltage of 10 volts is applied and the output voltage measured is 10 millivolts when the amplifier gain is 1000. Substituting these values in the equation for common-mode rejection, we find the common-mode rejection to be the common-mode voltage of 10 volts times the amplifier gain of 1000 divided by the output voltage of 10 millivolts. The common-mode rejection ratio is 1 million to 1, or 120-db.

Since the common-mode rejection is a ratio, it is independent of the absolute value of the common-mode voltage. However, it should be noted that certain types of differential amplifiers will withstand only a small amount of common-mode voltage. Notably, the bridge type amplifiers can operate with some 10 to 15 volts of common-mode voltage, while isolated amplifiers can withstand up to 300 volts, depending upon the insulation resistance of the isolator transformers. It is very important, however, to relate the specification for common-mode rejection to the value of unbalance in the amplifier's input circuit. Obviously, if there were no unbalance the common-mode rejection will be very high. The most common practice is to place zero ohms in one lead and 1000 ohms in the other lead and measure the common-mode rejection ratio. Then switch the unbalance around to the opposite input leads and again measure

the common-mode rejection ratio. The true common-mode specifications should be the lowest ratio which is observed.

This measurement is not restricted to dc measurements, and the ac common-mode rejection can be similarly measured by substituting an ac voltage source for the common-mode voltage. Generally speaking, well isolated amplifiers will yield common-mode rejection ratios of 140 to 160 db at dc, 120 db at 60 cps, and 100 db at 400 cps, with as much as 1000 ohms unbalance in either differential input lead.

In modern instrumentation systems, quantities of transducers are attached to test specimens such as nose cones, rocket engines, air foils, etc. These test specimens are usually located at installations some distance from the data reduction center. The transducers produce very small electrical signals, proportional to physical quantities such as temperature, strain and pressure.

An important application of these amplifiers is the amplification of these low-level signals in the instrumentation system. Figure 9 shows the schematic of a typical single-channel installation for such an application. Observe that the transducer is shown connected

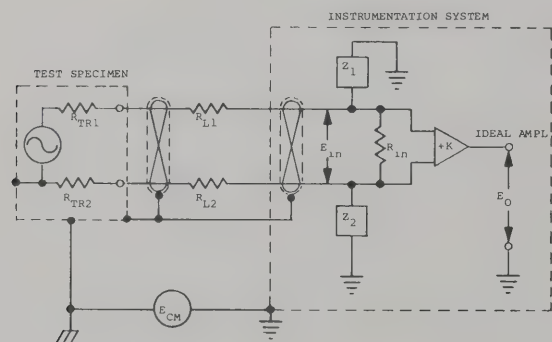


Fig. 9. Differential Amplifier Installation

to the test specimen ground. This is representative of actual practice, since, in many instances, it is impossible to achieve complete isolation. The transducer output resistance is represented by resistors  $R_{TR1}$  and  $R_{TR2}$ .

The output of the transducer is connected through an arbitrary length of twisted, shielded-pair cable to the input of the instrumentation system. The resistances of these lines are represented by  $R_{L1}$  and  $R_{L2}$ , and they are not necessarily equal, especially in thermocouple circuits.

Due to complex ground currents, both natural and man-made, the test specimen and the instrumentation system are never at quite the same potential. This is so regardless of whether the two units are individually grounded or are bussed to a common ground. Under certain circumstances, differences in electrical potential between the two ground points can be as great as 115 volts dc or ac. This potential difference is the common-mode voltage, and is designated  $E_{cm}$ .

If the transducer and the transducer output wiring are surrounded by a shield which is kept at transducer ground potential, the small transducer signal will arrive at the instrumentation system essentially intact. An ideal amplifier of gain  $K$  is shown within the instrumentation system. Its most significant shortcomings from the standpoint of common-mode rejection are represented schematically as being external to this amplifier. These include a differential input impedance of less than infinity, represented by  $R_{IN}$ , and some resistive and capacitive coupling between each input terminal and system ground, represented by impedances  $Z1$  and  $Z2$ .

This figure graphically illustrates the relation of the Wheatstone bridge effect to common-mode rejection. If the amplifier in the instrumentation system is a bridge type amplifier, then the impedances  $Z1$  and  $Z2$  are fixed at some relatively low value and the resistances  $R_{L1}$  and  $R_{L2}$  will include the bridge input resistors. In general, the common-mode rejection ratio of the system will depend upon the balance which can be maintained in the Wheatstone bridge. On the other hand, if the amplifier is a potentiometric input, floating, isolated amplifier, then the resistances  $R_{L1}$  and  $R_{L2}$  will be only that of the transmission lines and the impedances  $Z1$  and  $Z2$  will be very high, depending on the amount of



isolation which is achieved in the dc isolator. Typical figures for this leakage impedance are 10,000 ohms resistance and 2.7 micro-microfarads capacitance yielding a leakage impedance at 60 cps of about 1000 megohms.

Under the worst conditions, the resistances  $R_{TR1}$  and  $R_{L1}$  could be zero while the sum of  $R_{TR2}$  and  $R_{L2}$  might be 1000 ohms. In this case, an equivalent input voltage caused by the common-mode voltage source would be created by the IR drop through  $R_{TR2}$  and  $R_{L2}$ . The amount of this voltage depends upon the ratio of the leakage impedance to the sum of transducer and line resistance. In our example, the equivalent voltage would be equal to the common-mode voltage times the leakage impedance of 1000 megohms divided by the sum of transducer and line resistance of 1000 ohms.

Since the common-mode rejection is defined as the ratio of the common-mode voltage to the equivalent of the input voltage, this ratio turns out to be 1000 megohms divided by 1000 ohms, or 1 million to 1, or 120-db at 60 cps.

From the discussion of the previous paragraphs, it is apparent that most amplifiers achieve differential operation and hence common-mode rejection through the use of either (1) a bridge configuration, or (2) an isolator. Both approaches have their advantages and their shortcomings.

The bridge technique can offer high gain accuracy, high gain stability, low drift and wide bandwidth, but common-mode rejection depends on the balance which can be achieved and maintained among the two transducer legs, the input wiring and the built-in bridge resistors. Noise referred to the input, in a well-designed bridge amplifier, will necessarily be higher than in a well-designed potentiometric amplifier.

Using an isolator, very high common-mode rejection ratios can be maintained over a wide range of source resistance unbalance, but the isolator reduces the gain accuracy, gain and zero stability, bandwidth and available output current. It should be obvious that, if a system hook-up can be found which achieves common-mode

rejection with a floating amplifier, a more accurate and cheaper system will result because the isolator is eliminated. Two approaches are possible: float the transducer or source from the common-mode voltage, or float the amplifier and its load from system ground. The success of either approach depends on the degree to which certain leakage impedances can be kept high.

It is very important to consider how the common-mode voltage originates. In measuring the IR drop across a resistor, for example, in a circuit where one end of the resistor is not at ground potential, the common-mode voltage source is obviously the voltage from one end of the resistor to ground, and the leakage path can easily be computed or measured. In making temperature or strain measurements on an airfoil which is purposely heated by induced currents, common-mode voltages are created by the IR drop of the heating currents passing through the skin resistance.

In installations where the transducers are situated remotely from the measuring system which houses the amplifiers, 60-cycle common-mode voltages can exist between the two sub-systems, even though they are bussed together with a heavy copper strap, because current supplied to the remote system to operate motors, lights, heaters, etc., may pass through the ground or grounding straps. Each installation or application differs from all others in some way, and each should be considered and analyzed separately.

These considerations are especially important when the floating transducer system of Figure 10 is to be used.

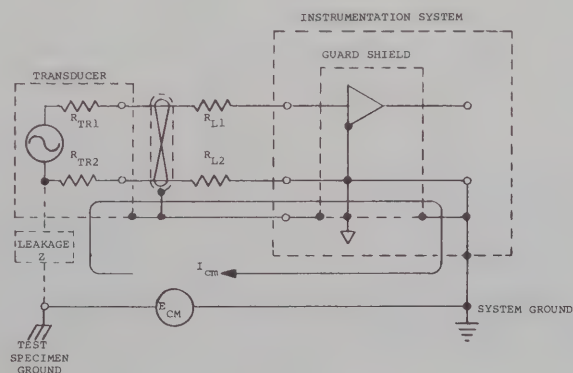


Fig. 10. Common-Mode Rejection With Guarded Input Single-Ended Amplifier

The amplifier output and guard shield are shown connected to system ground, and the shielding is carried back to include the input wiring shield and to surround the transducer. By keeping the coupling impedance  $Z$  from transducer to common-mode source high, little current will flow from the common-mode source through  $R_{tr2}$  and  $R_{L2}$  to ground, and only a small differential input across A and B will be caused by the common-mode voltage. The common-mode rejection will be  $CMR =$

$$\frac{Z}{R_{tr2} + R_{L2}}.$$

Many transducers, especially those which convert pressure to voltage, can offer a high leakage impedance. The resistive component, generally many thousands of megohms, is no problem. Capacitance, on the other hand, may range as high as 10 to 50  $\mu\text{f}$ . Taking a typical value of 30  $\mu\text{f}$ , the leakage impedance at 60 cps would be about 90 megohms. To achieve a CMR of 120-db, the sum of transducer and line resistances in the lower transducer leg would have to be 90 ohms or less, which is not at all an unreasonable value. On the other hand, strain gages which are cemented to the test sample can have much higher leakage capacitances and lower leakage resistances and thermocouples may even be welded to the sample, completely destroying the common-mode rejection. Such situations require the use of a floating load if a three-terminal (not differential) amplifier is to be used.

In the floating load system, shown in Figure 11, the common-mode source is connected to the transducer, the transducer shield, and the amplifier guard. The entire system of transducer, amplifier and load follows the common-mode voltage which exists with respect to instrumentation system ground. As before, the common-mode rejection ratio is  $CMR = \frac{Z}{R_{tr2} + R_{L2}}$ . In the ASTRODATA TDA-874 Amplifier, for example, the direct or unguarded coupling from points B or E to instrumentation system ground is at least 10,000 megohms resistance and about 2.7  $\mu\text{f}$  capacitance, resulting in a leakage impedance of about 1,000 megohms at 60 cps. To

this must be added in parallel the leakage impedance of the output wiring and the load when the CMR for the system is to be figured.

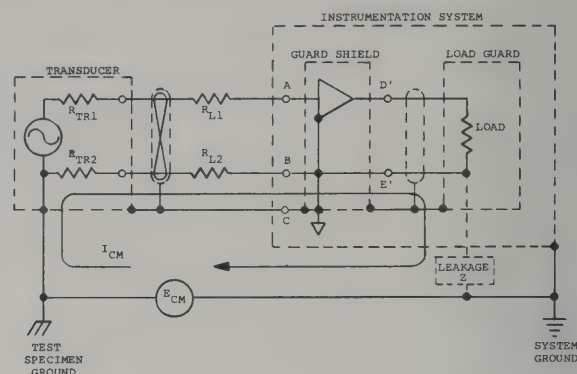


Fig. 11. Common-Mode Rejection With Guarded Output Single-Ended Amplifier

The most common type of floating load is the galvanometer. Available from several manufacturers with a wide variety of sensitivities and frequency responses, galvanometers can be constructed to offer large leakage impedances. As with some transducers, the resistive component of leakage is usually no problem. Measurements made at ASTRODATA indicate that unguarded capacitance in some galvanometers made by one manufacturer is as low as 27  $\mu\text{f}$ , while that in some galvanometers made by other manufacturers runs about 40 to 50  $\mu\text{f}$ . This is because guard shielding in the former units is carried right up to the galvanometer movement, while in the other units, shielding stops at the input terminals.

Galvanometers are generally less accurate than A-to-D converters; therefore, the acceptable CMR may be lower, depending on the magnitude of the common-mode voltage which will be encountered.

Taking typical unguarded capacitances of 50  $\mu\text{f}$  for the galvanometer and 2.7  $\mu\text{f}$  for the amplifier, the leakage impedance turns out to be 50 megohms at 60 cps. As much as 500 ohms resistance (again, a reasonable value) can appear in the lower transducer leg without reducing the CMR below 100 db.



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Astrodata **standard** instrumentation amplifiers are designed for use with data acquisition systems to raise low level signals to useful levels for measurement, conditioning, monitoring, feedback loop control and indication. Many performance options are available to adapt these standard amplifiers to a wide range of applications.

Where custom designs are necessary, Astrodata's experience provides an exceptionally well qualified basis for meeting your individual requirements.

**TDA-875 Dual-Mode Amplifier** for both portable cabinet and rack mounting installations.

**TDA-875 Dual-Mode Amplifiers** for both differential and single-ended, floating amplification after low-level commutation.

DIFFERENTIAL BANDWIDTH dc — 5 kc  
SINGLE ENDED BANDWIDTH dc — 150 kc  
COMMON MODE REJECTION Greater than 120 db dc to 60 cps  
RECOVERY TIME FROM 20 VOLT OVERLOAD 1 millisecond

**TDA-874 Wide-Band Single Ended Amplifier** for amplification after low level commutation.

BANDWIDTH  
dc — 150 kc  
GAINS AVAILABLE FROM  
1 — 5000  
NOISE REFERRED  
TO INPUT  
5 mv rms  
INPUT RESISTANCE  
Greater than  
100 megohms



**TDA-874G Galvanometer Driver Amplifier** for raising low level sources to galvanometer levels.

Built-in Galvanometer  
Overload Protection  
ADJUSTABLE DAMPING  
RESISTOR  
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GAIN RANGE  
0.5 — 5000  
INPUT RESISTANCE  
Greater than  
100 megohms



**TDA-880 Differential Amplifier** for single channel or high-level multiplexing systems.

BANDWIDTH  
dc to 200 cps  
LOW NOISE  
1  $\mu$ v rms  
Built-in Filtering  
Available to Restrict  
Bandwidth for  
Commuted Data  
Systems.



**TDA-110 Chopper Stabilized Operational Amplifier.** Versatile modular amplifier for analog control systems.



BANDWIDTH dc — 250 kc  
Long Term Stability, Constant  
Gain-Bandwidth  
VOLTAGE OFFSET ADJUSTABLE TO ZERO  
 $\pm 1$  mv nom. range  
CURRENT OFFSET ADJUSTABLE TO ZERO  
 $\pm 0.001$   $\mu$ a nom. range

**TDA-121 Nanovoltmeter** provides 0.1  $\mu$ v full scale bridge balance detector for standards and calibration work in the field as well as laboratories.

FULL SCALE RANGES  
 $\pm 0.1$   $\mu$ v to  $\pm 100$  mv  
INPUT RESISTANCE  
ALL RANGES  
1 megohm  
Built-in Overload  
Indicator.



**TDA-120 Ultrasensitive Amplifier** gives you high gain/low noise amplification for seismic transducer signals, cryogenic studies, strain gage signals.

Gains From 1000 to  
100,000 (optional to  
3,000,000).  
BANDWIDTH  
dc — 100 cps  
NOISE  
0.05  $\mu$ v rms  
referred to input  
INPUT RESISTANCE  
1 megohm



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*Epsco-West* 

# MODEL TDA-875 SOLID-STATE DIFFERENTIAL AMPLIFIER



designed specifically for applications where high common  
mode rejection, extraordinarily high input impedance and  
the ultimate in reliability are essential

Specifically designed for use in applications where high common mode rejection, extraordinarily high input impedance and the ultimate in reliability are essential.

- 3000 megohms input to output isolation
- 100 megohms input resistance
- 120 DB common mode rejection
- 300 volts common mode level range
- Differential or single-ended input modes
- Bandwidth 5KC differential, 150 kc single-ended
- Drift less than 2 microvolts per week
- Noise less than 2 microvolts DC to 20 cps
- Entirely solid-state
- Integral power supplies
- Portable or rack-mounted

The Model TDA-875 Amplifier is entirely solid-state. It contains an integral power supply which operates from a 117-volt, 60 cps line, requiring only 15 watts of power. Chopper drive circuits are also included with each amplifier.

Two modes of operation are available in the Model TDA-875 amplifier: differential and single-ended (Potentiometric); selection may be made by means of a front panel control. Five fixed gains are also chosen by a front panel switch.

In its differential mode, the amplifier provides 10 volts at 10 milliamperes as its full scale output; in its single-ended mode, full scale output is 10 volts at 50 milliamperes. In both modes, the input resistance is greater than 100 megohms. This unusually high value ensures that the entire transducer volt-

age will appear at the amplifier input terminals. Changes in transducer or line resistance will, therefore, have little consequence.

Triple electrostatic shielding guarantees complete electrostatic input-to-output isolation in the differential mode. Input terminals (two signal input terminals and one guard) are isolated from and have no direct connection with the output terminals (two un-grounded terminals and one guard). Signal information is conveyed by magnetic coupling from the floating, guarded input domain to the floating, separately-guarded, output domain. Appropriate electrostatic shielding is provided.

The Model TDA-875 Amplifier may be used as a wide-band, floating, single-ended, potentiometric amplifier by switching out the magnetic DC isolator. In this potentiometric capacity, one input terminal and one output terminal are common. Complete electrostatic shielding of input and output is retained, however. High common mode rejection can, therefore, be achieved when working into an isolated load.

Modular construction simplifies maintenance. The amplifier circuitry is mounted on three printed circuit cards. Servicing and testing may be accomplished while the amplifier is operating, by using available circuit card extenders.

The Model TDA-875 Amplifier may be mounted in the Model TDA-870A Carrying Case for easy portability, or in the Model TDA-870 Rack Adapter which holds 5 amplifiers in a standard 19-inch relay rack.

- HIGH GAIN
- WIDE BANDWIDTH
- NEGLIGIBLE DRIFT
- HIGH DC COMMON MODE REJECTION
- HIGH AC COMMON MODE REJECTION
- LOW NOISE
- FAST RISE TIME
- WIDE DYNAMIC RANGE
- INTEGRAL POWER SUPPLY
- RACK MOUNT AVAILABLE





# SPECIFICATIONS

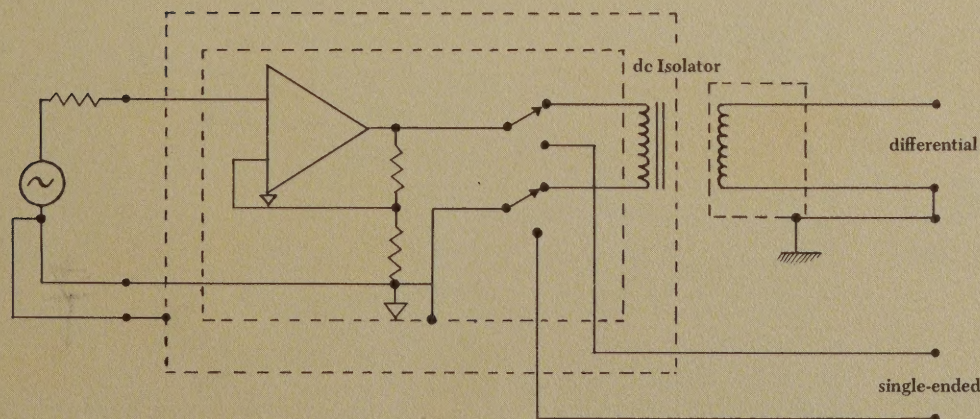
|                                                       |                                                                                                                                                                 |
|-------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Voltage Gain:                                         | Fixed steps of 1000, 500, 200, 100, 50. Lower gains optional.                                                                                                   |
| Gain Accuracy:                                        | $\pm 0.1\%$ DC to 1KC                                                                                                                                           |
| Gain Stability:                                       | $\pm 0.1\%$ DC to 1KC                                                                                                                                           |
| Linearity:                                            | $\pm 0.1\%$ DC to 300 cps, $\pm 0.3\%$ DC to 1KC.                                                                                                               |
| Input Impedance:                                      | Greater than 100 megohms shunted by .002 microfarad.                                                                                                            |
| Common Mode Level:                                    | $\pm 300$ volts DC, 117 volts AC.                                                                                                                               |
| Transient Common Mode Recovery:                       | 300 volt step of common mode voltage does not cause overload.                                                                                                   |
| Chopper Intermodulation:                              | Less than 0.1% DC to 1 KC.                                                                                                                                      |
| Drift — 40 Hours:                                     | $\pm 2$ microvolts referred to the input, plus $\pm 0.2\%$ of full scale at 25°C.                                                                               |
| Drift — 6 Months:                                     | $\pm 4$ microvolts referred to the input, plus $\pm 0.2\%$ of full scale at 25°C.                                                                               |
| Temperature Coefficient of Offset:                    | 1 microvolt per °C referred to the input.                                                                                                                       |
| Noise Referred to the Input:                          | Less than 2 microvolts peak-to-peak (99% confidence) from DC to 20 cps. Less than 5 microvolts rms from DC to 5 KC for source resistances of 1000 ohms or less. |
| Settling Time:                                        | 300 microseconds to within 1% of final value all ranges.                                                                                                        |
| Frequency Response:                                   | $\pm 1.0\%$ DC to 300 cps, down 3 db at 5 KC with 1 K load.                                                                                                     |
| Overload Recovery Time:                               | 300 microseconds or less to within 1% of final value from 500% overload.                                                                                        |
| Zero Adjustment Range:                                | $\pm 10$ microvolts nominal referred to the input on gain of 1000                                                                                               |
| Short Circuit Protection:                             | Sustained output short circuit will not damage amplifier.                                                                                                       |
| Output Voltage:                                       | $\pm 10$ volts, limited at $\pm 13$ volts.                                                                                                                      |
| Output Current:                                       | $\pm 10$ ma.                                                                                                                                                    |
| Output Resistance:                                    | Less than 25 ohms.                                                                                                                                              |
| Maximum Load Capacity:                                | 0.02 microfarad. Will not oscillate with any value of load capacity.                                                                                            |
| Minimum Load Resistance:                              | 1000 ohms.                                                                                                                                                      |
| Isolation between Input and Output or Input and Case: | 3000 megohms at 60 cps, essentially infinite at DC.                                                                                                             |
| Common Mode Balance Controls:                         | None.                                                                                                                                                           |
| Common Mode Rejection:                                | Greater than 120 db from DC to 60 cps, 100 db at 400 cps for 1000 ohms or less of line unbalance.                                                               |

## Single-Ended Operation (Potentiometric)

|                                    |                                                                                                                                                    |
|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------|
| Voltage Gain:                      | Fixed steps of 1000, 500, 200, 100, 50. Lower gains optional.                                                                                      |
| Gain Accuracy:                     | $\pm 0.1\%$ DC to 1 KC.                                                                                                                            |
| Gain Stability:                    | $\pm 0.01\%$ .                                                                                                                                     |
| Linearity:                         | $\pm 0.01\%$ at DC.                                                                                                                                |
| Input Impedance:                   | Greater than 100 megohms shunted by .002 microfarad.                                                                                               |
| Output Voltage:                    | $\pm 10$ volts DC to 10 KC.                                                                                                                        |
| Output Current:                    | $\pm 50$ ma DC to 10 KC.                                                                                                                           |
| Output Impedance:                  | Less than 1 ohm in series with 50 microhenries.                                                                                                    |
| Maximum Load Capacitance:          | 0.02 microfarad.                                                                                                                                   |
| Minimum Load Resistance:           | 200 ohms.                                                                                                                                          |
| Drift — 40 Hours:                  | $\pm 2$ microvolts referred to the input.                                                                                                          |
| Drift — 6 Months:                  | $\pm 4$ microvolts referred to the input.                                                                                                          |
| Temperature Coefficient of Offset: | 1 microvolt per °C referred to the input.                                                                                                          |
| Noise Referred to the Input:       | Less than 2 microvolts peak-to-peak (99% confidence) from DC to 20 cps. 5 microvolts rms, DC to 30 KC, for source resistance of 1000 ohms or less. |
| Settling Time:                     | 50 microseconds to within 1% of final value all ranges.                                                                                            |
| Frequency Response:                | $\pm 1\%$ to 10 KC, down 3 db at 150 KC.                                                                                                           |
| Overload Recovery Time:            | 50 microseconds or less to within 1% of final value for up to 500% overload.                                                                       |

## GENERAL

|                                                         |                                                                     |
|---------------------------------------------------------|---------------------------------------------------------------------|
| Crosstalk in Model TDA-870 Rack:                        | Maximum is less than noise level.                                   |
| Amplifier Power:                                        | 117 volts $\pm 10\%$ , 60-400 cps, 15 watts.                        |
| Dimensions:                                             |                                                                     |
| Model TDA-875 Amplifier:                                | 8.1" high x 3.20" wide by 19.40" deep.                              |
| Model TDA-870 Rack Mounting Adapter (hold 5 amplifiers) | 8.75" high x 21" deep including connectors. Fits standard 19" rack. |
| Model TDA-870A Portable Carrying Case:                  | 10" high x 3.40" wide x 23.50" deep.                                |
| Finish:                                                 | Panel light gray; marking, knobs and portable case slate blue.      |



MODEL TDA-875 SOLID-STATE DIFFERENTIAL AMPLIFIER



# MODEL TDA-875 SOLID-STATE DIFFERENTIAL AMPLIFIER



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